BIOLOGY EXPERIMENTS USER GUIDE

ADVANCED SECONDARY LEVEL

Senior 5

December, 2022

FOREWORD

Dear teacher,

Rwanda Basic Education Board (REB) is honoured to present the user guide for Biology experiments and practical activities for advanced Level (S5). This booklet will serve as a guide to competence-based teaching and learning to ensure consistency and coherence in the learning of Biology.

In this booklet, special attention was paid to practical activities that facilitate the learning process in which students can manipulate concrete materials, develop ideas, and make new discoveries during activities carried out individually or in pairs/ small groups.

In competence-based curriculum, practical activities open students' minds and provide them with the opportunities to interact with the world, use available tools, collect data, and effectively model real life problems.

For efficiency use of this booklet, your role as a teacher is to:

- Plan your lessons and prepare appropriate teaching materials. \
- Engage students through active learning methods.
- Organize groups for students considering the importance of social constructivism.
- Provide supervised opportunities for students to develop different competences by giving tasks which enhance critical thinking, problem solving, research, creativity and innovation, communication, and cooperation.
- Support and facilitate the learning process by valuing students' contributions in the practical activities.
- Guide students towards the conclusion on the results of the experiments.
- Encourage individual, peer, and group evaluation of the work done and use appropriate competence-based assessment approaches and methods.

To facilitate you in your teaching activities, the content of this guide is self-explanatory so that you can easily use it. It is divided in 3 parts:

The part I explains the structure of this guide and gives you the general introduction on the role of practical activities and lab experiments in the implementation of CBC.

The part II gives the list of purchased Biology kits.

The part III explains selected practical activities and how you can facilitate them in lessons.

Even though this guide contains practical activities, they are not enough, as

expert and experienced teacher, you can guide students to carry out more practical activities using improvised teaching resources.

I wish to sincerely extend my appreciation to the people who contributed towards the development of this guide, particularly REB and SPIU staff who organized the whole process from its inception. Special appreciation goes also to UR-CE , IEE and AIMS staff, teachers and independent experts in education who supported the exercise throughout. Any comment or contribution would be welcome for the improvement of this booklet for next versions.

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Director General, REB

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I wish to express my appreciation to the people who played a major role in the development and the editing of the Biology Experiments User Guide for Advanced secondary Level S5. It would not have been successful without their active participation.

Special thinks go to UR-CE, IEE, AIMS, independent peoples, teachers, illustrators, designers and all others individuals whose effort in one way or the other contributed to the success of the development of this User Guide.

I owe gratitude to the Rwanda Basic Education Board staff particularly those from Curriculum Teaching and Learning Resources Department who were involved in the whole process of the development work.

Joan MURUNGI
Head of CTLR Department

LIST OF ACRONYMS

REB: Rwanda Basic Education Board

CBC: Competence-based curriculum

ICT: Information Communication Technology

Lab: Laboratory

STEM: Science Technology Engineering and Mathematics

KBC: Knowledge Based Curriculum

SET: Science and Elementary Technology

IEE: Inspire, Educate and Empower Rwanda

AIMS: African Institute for Mathematical and Sciences

UR-CE: University of Rwanda - College of Education

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PART 1: GENERAL INTRODUCTION

1. Structure of the user guide

The Biology Experiments User Guide is divided in 3 parts:

The part I explains the structure of this book and gives you the general introduction on the role of practical activities and lab experiments in the implementation of CBC.

The part II gives the list of materials (apparatuses and chemicals)

The part III details the practical activities and how you can facilitate them in lessons.

2. Laboratory experiments in the Competence Based Curriculum

A competence-based curriculum (CBC) focuses on what learners can do and apply in different situations by developing skills, attitudes, and values in addition to knowledge and understanding. This learning process is learner-focused, where a learner is engaged in active and participatory learning activities, and learners finally build new knowledge from prior knowledge. Since 2015, the Rwanda Education system has changed from KBC to CBC for preparing students that meet the national and international job market requirements and job creation. Therefore, implementing the CBC education system necessitates qualitative laboratory practical works for mathematics and science as more highlighted aspects.

In addressing this necessity, laboratory experiments play a major role. A learner is motivated to learn sciences by getting involved in handling various concrete manipulative in various activities. In addition to activities, games in sciences also help the child's involvement in learning by strategizing and reasoning.

For learning biology concepts through the above-mentioned approach, a learner-centred science kits have been developed for the learners of lower and advanced Secondary schools. The kits include various kit items along with a manual for performing activities.

The kit broadly covers the activities in the areas of biology, chemistry and physics.

The kit has the following advantages:

- Availability of necessary and common materials at one place
- Multipurpose use of items
- Economy of time in doing the activities

- Portability from one place to another
- Provision for teacher's innovation
- Low-cost material and use of indigenous resources.

Apart from the kit, the user guide for laboratory and practical activities to be used by teachers was developed. This biology lab experiment user guide is designed to help biology teachers to perform high-quality lab experiments for biology subject. This user guide structure induces learner's interest, achievement, and motivation through the qualitative science lab experiments offered by their teachers and will finally lead to the targeted goals of the CBC education system, particularly in the field of Biology.

In CBC, learners hand on the materials and reveal the theory behind the experiment done. Here, experiments are done inductively, where experiments serve as an insight towards revealing the theory. Thus, the experiment starts, and theory is produced from the results of the experiment.

3. Type of lab experiments

The goal of the practical work defines the type of practical work and how it is organized. Therefore, before doing practical work, it is important to have a clear idea of the objective.

The three types of practical work that correspond with its three main goals are:

1. **Equipment-based practical work:** the goal is for students to learn to handle scientific equipment like using a microscope, doing titrations, making an electric circuit, etc.
2. **Concept-based practical work:** learning new concepts.
3. **Inquiry-based practical work:** learning process skills. Examples of process skills are defining the problem and good research question (s), installing an experimental setup, observing, measuring, processing data in tables and graphs, identifying conclusions, defining limitations of the experiment etc.

Note:

– To learn the new concept by practical work, the lesson should start with the practical work, and the theory can be explained by the teacher afterward (explore – explain).

Starting by teaching the theory and then doing the practical work to prove

what they have learned is demotivating and offers little added value for student learning.

- Try to avoid complex arrangements or procedures. Use simple equipment or handling skills to make it not too complicated and keep the focus on learning of the new concept.
- If this is not possible and is necessary to use new equipment or handling skills, then first exercise these skills before starting the concept-based practical work experiments.
- The experiments should be useful for all learners and not only for aspiring scientists. Try to link the practical work as much as possible with their daily life and preconceptions.

4. Organization, analysis, and interpretation of data

Once collected, data must be ordered in a form that can reveal patterns and relationships and allows results to be communicated to others. We list goals about analysing and interpreting data. By the end of secondary education, students should be able to:

- Analyze data systematically, either look for relevant patterns or test whether data are consistent with the initial hypothesis.
- Recognize when data conflict with expectations and consider what revisions in the initial model are needed.
- Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and ICT to compare, analyze, summarize, and display data and explore relationships between variables, especially those representing input and output.
- Evaluate the strength of a conclusion that can be inferred from any data set, using appropriate grade-level mathematical and statistical techniques.
- Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlational relationships.
- Collect data from physical models and analyze the performance of a design under a range of conditions.

5. Organising lab experiments

a) Methods of organizing a practical work

There are 3 methods of organizing practical work:

- Each group does the same experiments at the same time

All learners can follow the logical sequence of the experiments, but this implies that a lot of material is needed. The best group size is 3, as all learners will be

involved. With bigger groups, you can ask to do the experiment twice, where learners change roles.

– Experiments are divided among groups with group rotation

Each group does the assigned experiment and moves to the next experiment upon a signal by the teacher. At the end of the lesson, each group has done every experiment. This method saves material but is not perfect when experiments are ordered in a logical way. In some cases, the conclusion of an experiment provides the research question for the next experiment. In that case, this method is not very suitable.

The organization is also more complex. Before starting the lesson, the materials for each experiment should be placed in the different places where the groups will work. Also, the required time for each experiment should be about the same. Use a timer to show learners the time left for each experiment. Provide an extra exercise for fast groups.

– All experiments are divided among groups without group rotation

Each group does only one or two experiments. The other experiments are done by other groups. Afterward, the results are brought together and discussed with the whole class. This saves time and materials, but it means that each learner does only one experiment and 'listens' to the other experiments' description. The method is suitable for experiments that are optional or like each other. It is not a good method for experiments that all learners need to master.

b) Preparation of a practical work

When preparing a practical work, do the following:

– Have a look at the available material at school and make a list of what you can use and what you need to improvise.
– Determine the required quantities by determining the method (see above).
– Collect all materials for the experiments in one place. If learners' group is small, they can come to get the materials on that spot, but with more than 15 learners, this will create disorder. In that case, prepare for each group a set of materials and place it on their desk.
– Test all experiments and measure the required time for each experiment.
– Prepare a nice but educational extra task for learners who are ready before the end of the lesson.
– Write on the blackboard how groups of learners are formed.

c) Preparation of a lesson for practical work

In the lesson plan of a lesson with practical work, there should be the following phases:

1. The introduction of the practical work or the 'excite' phase consists of formulation of a key question, discrepant event, or a small conversation to motivate learners and make connections with daily life and learners' prior knowledge.
2. The discussion of safety rules for the practical work:

– Only work at the assigned place; do not walk around in the class if this is not asked.
– Long hairs should be tied together, and safety eyeglasses should be worn for chemical experiments.
– Only the material needed for the experiment should be on the table.
– The practical work instructions: how groups are formed, where they get the materials, special treatment of materials (if relevant), what they must write down…
– When the practical work materials aren't yet at the correct location, then distribute them now. Once learners have the materials, it is more difficult to get their attention.

3. How to conduct a practical work:

– learners do the experiments, while the teacher coaches by asking questions (Explore phase).
– The practical work should preferably be processed immediately with an explain phase. If not, this should happen in the next lesson.

4. How to conclude the lesson of a practical work:

– Learners refer to instructions and conduct the experiment,
– Learners record and interpret recorded data,
– Cleaning the workspace after the practical work (by the learners as much as possible).

6. Role and responsibilities of teacher and learners in lab experiment

Roles and responsibilities of teacher during a lab experiment

Before conducting an experiment, the teacher will do the following:

– Decide how to incorporate experiments into class content best,
– Prepare in advance materials needed in the experiment,

- Prepare protocol for the experiment,
- Perform in advance the experiment to ensure that everything works as expected,
- Designate an appropriate amount of time for the experiment - some experiments might be adapted to take more than one class period, while others may be adapted to take only a few minutes.
- Match the experiment to the class level, course atmosphere, and your students' personalities and learning styles.
- Verify lab equipment before lab practices.
- Provide the working sheet and give instructions to learners during lab session.

During practical work, the teacher's role is to coach instead of helping with advice or questions. It is better to answer a learner's question with another question than to immediately give the answer or advice. The additional question should help learners to find the answer themselves.

- Prepare some pre-lab questions for each practical work, no matter what the type is.
- Try and start the practical work: start with a discrepant event or questions that help define the problem or questions that link the practical work with students' daily life or their initial conceptions about the topic.
- Use coaching questions during the practical work: 'Why do you do this?', 'What is a control tube?', ''What is the purpose of the experiment?', 'How do you call this product?', 'What are your results?' etc.
- Use some questions to end the practical work: 'What was the meaning of the experiment?', 'What did we learn?', 'What do we know now that we didn't know at the start?', 'What surprised you?'etc.
- Announce the end of the practical work 10 minutes before giving learners enough time to finish their work and clean their space.

Role of a lab technician during a laboratory-based lesson

In schools having laboratory technicians, they assist the science teachers in the following tasks:

- Maintaining, calibrating, cleaning, and testing the sterility of the equipment,
- Collecting, preparing and/or testing samples,
- Demonstrating procedures.

Learners' responsibilities in the lab work

During the lab experiment, both learners have different activities to do; the table

barrow summarizes them. General learner's activities are:

- Experiment and obtain data themselves,
- Record data using the equipment provided by the teacher,
- Analyze the data often this involves graphing it to produce the related graph,
- Interpret the obtained results and deduct the theory behind the concept under the experimentation,
- Discuss the error in the experiment and suggest improvements,
- Cleaning and arranging material after a lab experiment.

7. Safety rules and precautions during lab experiments

Regardless of the type of lab you are in, there are general rules enforced as safety precautions. Each lab member must learn and adhere to the rules and guidelines set, to minimize the risks of harm that may happen to them within the working environment. These encompass dress' code, use of personal protection equipment, and general behaviour in the lab. It is important to know that some laboratories contain certain inherent dangers and hazards.

Therefore, when working in a laboratory, you must learn how to work safely with these hazards to prevent injury to yourself and other lab mates around you. You must make a constant effort to think about the potential hazards associated with what you are doing and think about how to work safely to prevent or minimize these hazards as much as possible.

Before doing any scientific experiment, you should make sure that you know where the fire extinguishers are in your laboratory, and there should also be a bucket of sand to extinguish fires. You must ensure that you are appropriately dressed whenever you are near chemicals or performing experiments. Please make sure you are familiar with the safety precautions, hazard warnings, and procedures of the experiment you perform on a given day before you start any work. Experiments should not be performed without an instructor in attendance and must not be left unattended while in progress.

A. Hygiene plan

A laboratory is a shared workspace, and everyone has the responsibility to ensure that it is organized, clean, well-maintained, and free of contamination that might interfere with the lab members' work or safety.

For waste disposal, all chemicals and used materials must be discarded in designated containers. Keep the container closed when not in use. When in doubt, check with your instructor.

B. Hazard warning symbols

To maintain a safe workplace and avoid accidents, lab safety symbols and signs need to be posted throughout the workplace.

Chemicals pose health and safety hazards to personnel due to innate chemical, physical, and toxicological properties. Chemicals can be grouped into several different hazard classes. The hazard class will determine how similar materials should be stored and handled and what special equipment and procedures are needed to use them safely.

Each of these hazards has a different set of safety precautions associated with them.

The annex 1 shows hazard symbols found in laboratories and the corresponding explanations.

C. Safety rules

Safety is the number one priority in any laboratory. All students are required to know and comply with good laboratory practices and safety norms; otherwise, they will be asked to leave the laboratory. Make sure you understand all the safety precautions before starting your experiments, and you are requested to help your learners to understand too.

The following are some general guidelines that should always be followed:

Lab coat

While working in the lab, everyone must always wear a lab coat (Figure 1) to prevent incidental and unexpected exposures to the skin and clothing. The primary purpose of a lab coat is to protect against splashes and spills. The lab coat must be wrist-fitted and must always keep buttoned. A lab coat should be non-flammable and should be easily removed.

Safety glasses

For eyes protection, goggles must always be worn over by all persons in the laboratory while students are working with chemicals. Safety glasses, with or without side-shields, are not acceptable. The eyes protection safety indicates the possibility of chemical, environmental, radiological, or mechanical irritants and hazards in the laboratory.

Breathing Masks

Respirators are designed to prevent contamination from volatile compounds that may enter in your body through the respiratory system. “Half mask” respirators (Figure3) cover just the nose and mouth; “full face” respirators

cover the entire face, and "hood" or "helmet" style respirators cover the entire head. The breathing mask safety sign lets you know that you are working in an area with potentially contaminated air.

Eye Wash Station

Eyes wash stations consist of a mirror and a set of bottles containing saline solution that can be used to wash the injured eye with water. The eye wash station is intended to flood the eye with a continuous stream of water.

Eyes wash stations provide a continuous, low-pressure stream of aerated water in laboratories where chemical or biological agents are used or stored and in facilities where non-human primates are handled. The eyewash stations should easily be accessed from any part of the laboratory, and if possible, located near the safety shower so that, if necessary, the eyes can be washed while the body is showered.

Footwear

Shoes that cover entirely the toes, heel, and top of the foot provide the best general protection (Figure 1.5). Closed shoes must always be worn while in the laboratory, regardless of the experiment or curricular activity. Shoes must fully cover your feet up to the ankles, and no skin should be shown. Socks do not constitute a cover replacement for shoes. Sandals, backless and open shoes are unacceptable.

Gloves

When handling chemical, physical, or biological hazards that can enter the body through the skin, it is important to wear the proper protective gloves. Butyl, neoprene and nitrile gloves are resistant to most chemicals, e.g., alcohols, aldehydes, ketones, most inorganic acids, and caustics.

Hair dressing

If hair is long, it must be tied back. It is good to report all accidents including minor incidents to your instructor immediately.

Eat and drink

Never drink, eat, taste, or smell anything in the laboratory unless you are allowed by the lab instructor.

Hot objects

Never hold very hot objects with your bare hands. Always hold them with a test tube holder, tongs, or a piece of cloth or paper.

8. Guidance on the Management of lab materials (Storage Management, Repairing and Disposal of Lab equipment and chemicals)

Keeping and cleaning up

Working spaces must always be kept neat and cleaned up before leaving. Equipment must be returned to its proper place. Keep backpacks or bags off the floor as they represent a tripping hazard. Open flames of any kind are prohibited in the laboratory unless specific permission is granted to use them during an experiment.

Management of lab materials

A science laboratory is a place where basic experimental skills are learned only by performing a set of prescribed experiments. Safety procedures usually involve chemical hygiene plans and waste disposal procedures. When providing chemicals, you must read the label carefully before starting the experiment. To avoid contamination and possibly violent reaction, do never return unwanted chemicals to their container. In the laboratory, chemicals should be stored in their original containers, and cabinets should be suitably ventilated. It is important to notify students that chemicals cannot be stored in containers on the floor. Sharp and pointed tools should be stored properly.

Students should always behave maturely and responsibly in the laboratory or wherever chemicals are stored or handled.

Hot equipment and glassware handling

Hazard symbols should be used as a guide for the handling of chemical reagents. Chemicals should be labeled as explosives, flammable, oxidizers, toxic and infectious substances, radioactive materials, corrosives etc. All glassware should be inspected before use, and any broken, cracked, or chipped glassware should be disposed of in an appropriate container. All hot equipment should be allowed to cool before storing it.

All glassware must be handled carefully and stored in its appropriate place after use. All chemical glass containers should be transported in rubber or polyethylene bottle carriers when leaving one lab area to enter another. When working in a lab, do never leave a hot plate unattended while it is turned on. It is recommended to handle hot equipment with safety gloves and other appropriate aids but never with bare hands. You must ensure that hands, hair, and clothing are kept away from the flame or heating area and turn heating devices off when they are not in use in the laboratories.

Waste disposal considerations

Waste disposal is a normal part of any science laboratory. As teachers or students perform demonstrations or laboratory experiments, chemical waste is generated.

These wastes should be collected in appropriate containers and disposed of according to local, state, and federal regulations. All schools should have a person with the responsibility of being familiar with this waste disposal. In order to minimize the amount of waste generated and handle it safely, there are several steps to consider.

Sinks with water taps for washing purposes and liquid waste disposal are usually provided on the working table. It is essential to clean the sink regularly. Notice that you should never put broken glass or ceramics in a regular waste container. Use a dustpan, a brush, and heavy gloves to carefully pick-up broken pieces, and dispose of them in a container specifically provided for this purpose. Hazardous chemical waste, including solvents, acids, and reagents, should never be disposed of down sewer drains. All chemical waste must be identified properly before it can be disposed of. Bottles containing chemical waste must be labeled appropriately. Labeling should include the words "hazardous waste." Chemical waste should be disposed of in glass or polyethylene bottles. Plastic coated glass bottles are best for this purpose. Aluminum cans that are easily corroded should not be used for waste disposal and storage.

Equipment Maintenance

Maintenance consists of preventative care and corrective repair. Both approaches should be used to keep equipment in working order. Records of all maintenance, service, repairs, and histories of any damage, malfunction, or equipment modification must be maintained in the equipment logs. The record must describe hardware and software changes and/or updates and show the dates when these occurred. Each laboratory must maintain a chemical inventory that should be updated at least once a year.

9. Student Experiment Work Sheet

There should be a sheet to guide students about how they will conduct the experiment, materials to be used, procedures to be followed and the way of recording data. The following is a structure of the student experiment worksheet. It can be prepared by teacher or be availed from the other level.

a. Date
b. Name of student/group
c. The title of experiment
d. Type of experiment (concept, equipment and inquiry based)

e. Objective(s) of the experiment
f. Key question(s)
g. Materials (equipment/instrument, resources, etc…)
h. Procedures & Steps of experiment
i. Schematic reference if required.
j. Data recording and presentation

Number of tests	Types/Item/Variables	Comments/Observations
1		
2		
3		
Etc		

a. Reflective questions and answers

Question1

Question 2

Question 3

b. Answer for the key question

10. Report Template for Learner

After conducting a laboratory experiment, students should write a report about their findings and the conclusion they took.

The report to be made depends on the level of students. The report done by primary school learners is not the same us the one to be made by secondary school learners.

The following is a structure of the report to be made by a group of secondary school learners.

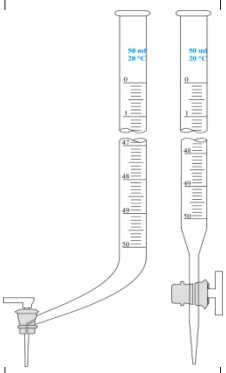
1. Introduction (details related to the experiment: Students identification, date, year, topic area, unit title and lesson).
2. The title of experiment.
3. Type of experiment (concept, equipment and inquiry based)
4. Objective(s) of the experiment.
5. Key question(s)

6. Materials (equipment/instrument, resources, etc…)
7. Procedures & Steps of experiment
8. Schematic reference if required.
9. Data recording
10. Data analysis and presentation (Plots, tables, pictures, graphs)
11. Interpretation/discussion of the results, student alternative ideas form observation.
12. Theory or Main ideas concept, formulas, and application).
13. Conclusion (answer reflective questions and the key question).

As a conclusion, there are safety rules and precautions to consider before, during and at the end of a lab experiment. We hope teachers are inspired to conduct lab experiments in a conducive Competence Based Curriculum way.

PART II: LIST OF MATERIALS FOR BIOLOGY LAB

II.1 List of main kit items and lab materials distributed in schools

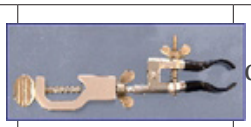
#	Item	Picture	Description of uses
1.	Beaker		Used to hold and heat liquids. Multipurpose and essential in the laboratory.
2.	Brushes		Used to easily clean the inside of a test tubes and other glassware.
3.	Buchner funnel		Used with vacuum flask for performing vacuum filtration.
4	Bunsen burner		First, make sure your workspace is free of potential fire hazards. Connect the gas line and ignite the burner. Adjust the metal collar and needle gas valve at the burner's base. When you're finished, close the air and gas ports, shut off the gas main line, and put the burner away once it's cool. Bunsen burner is used for heating and exposing items to flame.
5.	Burette		Before delivering any solution, record the initial burette reading in your notebook. Open the stopcock by twisting it 90 degrees into the vertical position and allow the solution to drain. As you near the desired volume, slow the flow by turning the stopcock back toward the closed position. You should be able to control the burette to deliver one drop at a time. When the desired volume has been delivered, close the stopcock. Wait a couple of seconds, then record the final burette reading.

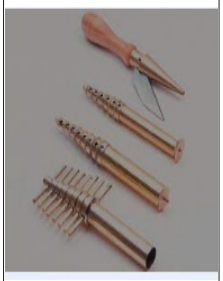
6.	Burette clamp		Used to hold burette on a ring stand.
7.	Clay triangle		Used to hold crucibles when they are being heated. They usually sit on a ring stand.
8.	Crucible with lid		Used to heat small quantities to very high temperatures.
9.	Crucible tong		Used to hold crucibles and evaporating dishes when they are hot.
10.	Disposable pipette		Used for moving small amounts of liquid from place to place. They are usually made of plastic and are disposable.
11.	Electronic balance		Used for weighing substances or objects, usually in grams. Place the electronic balance on a flat, stable surface indoors. Press the "ON" button and wait for the balance to show zeroes on the digital screen. Place the empty container you will use for the substance to be measured on the balance platform. Press the "Tare" or "Zero" button to cancel automatically the weight of the container. The digital display will show zero again.

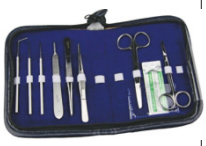
			Carefully add the substance to the container. Ideally this is done with the container still on the platform, but it may be removed if necessary. Avoid placing the container on surfaces that may have substances which will add mass to the container such as powders or grease. Place the container with the substance back on the balance platform if necessary and record the mass as indicated by the digital display.
12.	Erlenmeyer flasks/Conical flask		Used to heat, mix, and store liquids. The advantage to the Erlenmeyer Flask is that the bottom is wider than the top so it will heat quicker because of the greater surface area exposed to the heat.
13.	Evaporating dish		Used to recover dissolved solids by evaporation.
14.	Forceps		Used for picking up and moving small objects.
15.	Glass funnel & Polypropylene funnel	 	Used to pour liquids into any container so they will not be lost or spilled. They are also used with folded filter paper for filtration.
16.	Glass stir rod		Used to stir liquids. They are usually made of glass.

17.	Graduated cylinder/ measuring cylinder		Used to measure the volumes of liquids.
18.	Micropipette		Used for accurately measuring and delivering very small volumes of liquid-usually 1 mL or less. Steps to follow when using a micropipette. Select the volume. Set the tip. Press and hold the plunger at the first stop. Place the tip in the liquid. Slowly release the plunger. Pause for a second and then move the tip. Insert the tip into the delivery vessel. Press the plunger to the second stop.
19.	Mortar and pestle		Used to crush solids into powders for experiments, usually to better dissolve the solids.
20.	Pipette filler		How does a pipette filler work? Siphon liquid into the pipette to the desired level by squeezing valve “S” on the bottom of the pipette filler. This uses the vacuum created in the bulb to draw liquid into the pipette. Be careful not to draw liquid into the pipette filler. ... This allows you to release liquid at the desired rate and to the desired level.

21.	Pipette with pump		Used for accurately measuring and delivering small volumes of liquid-usually 0.1-10 mL.
22.	Ring clamp		Attached to a retort stand and with wire gauze used to hold beakers or flasks while they are heated by a gas burner.
23.	Retort stand and accessories		Used to hold items being heated. Clamps or rings can be used so that items may be placed above the lab table for heating by Bunsen burners or other items. Used also to hold burette
24.	Rubber stopper		Stoppers come in many different sizes. The sizes are from 0 to 8. Stoppers can have holes for thermometers and for other probes that may be used.
25.	Spatula		Used for moving small amounts of solid from place to place.
26.	Test tube		Used for storing, mixing, and heating small amounts of chemicals.
27.	Test tube holder		Used to hold test tubes while heating.
28.	Test tube rack		Used to hold test tubes while reactions happen in them or while they are not needed.
29.	Thermometer		Used to take temperature of solids, liquids, and gases.

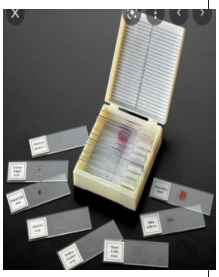
30.	Utility clamp		Used to attach test tubes and other glassware to retort stand.
31.	Vacuum filter flask		Used with vacuum line and Buchner funnel for vacuum filtration.
32.	Volumetric flask		Used to prepare solutions with accurate concentration.
33.	Wash bottle		Used to wash; rinse containers
34.	Watch glass		Used to hold solids when being weighed or transported. They should never be heated. Can also be used to cover beakers or other containers.
35.	Wire gauze		Used with a ring clamp to support glassware over a Bunsen burner.
36.	Borosilicate glass tube		Used to connect to other items of glassware or equipment to deliver chemicals, solvents, liquids, gases and other products.
37.	Rubber tube		Rubber tubing is often connected to a condenser, which is a laboratory tool used in the process of distillation. The rubber tubing helps cool water to flow in and out of the condenser and helps the heated water vapor in the condenser return to its liquid state.
38.	Borosilicate delivery tube		The delivery tube is particularly useful for bubbling a gas from a gas cylinder or stoppered vessel through a liquid.

39.	Rough		The rough is used for collecting gases, such as hydrogen, oxygen and nitrogen. Troughs require a liquid such as water.
40.	Beehive shelf		A beehive shelf is usually used to support a receiving jar or tube while a gas is being collected over water with a pneumatic trough.
41.	Syringe		They are often used for measuring and transferring solvents and reagents where a high precision is not required.
42.	Gas jar and cover		A container used for collecting gas from experiments.
43.	Clinostat		A clinostat is a device which uses rotation to negate the effects of gravitational pull on plant growth and development.
44.	Cork borers		used in a biology laboratory, is a metal tool for cutting a hole in a cork or rubber stopper to insert glass tubing. Cork borers usually come in a set of nested sizes along with a solid pin for pushing the removed cork (or rubber) out of the borer.
45.	Cover glasses		The cover glass serves two purposes: It protects the microscope's objective lens from contacting the specimen, and (2) It creates an even thickness (in wet mounts) for viewing.

46.	Dark blue plastic modelling clay pack of 500g		used for sculpting and building by children, students, etc.
47.	Visking (dialysis) tubing or suitable, size 2,normal diameter 14mm roll of 30 meters		Dialysis tubing, also known as Visking tubing, is an artificial semi-permeable membrane tubing used in separation techniques based on differential diffusion
48.	Dissecting kits		used for dissection, includes scissors, pins, scalpel handle; dressing forceps, 16 cm; mayo hager needle holder, 16 cm; teaser needle; angled teaser needle straight; tissue Forceps, 1:2, 16 cm. ets
49.	First aid Education response		In laboratory first aid kit includes: Triangle andages; bandages; pins for bandages; sterile dressings;plasters; antiseptic wipes;eye pad dressings and gloves
50.	**Microbiological inoculating loop handles** for inoculating wire		The inoculation handle can be used for a variety of applications in microbiology: inoculation, serial dilution, sterile sampling, transfer and spreading of microbiological samples. The inoculating loop is sterilised by passing it at an angle through the flame of a gas burner until the entire length of the wire becomes orange from the heat. In this way all contaminants on the wire are incinerated. Never lay the loop down once it is sterilised, or it may again become contaminated.

51.	**Microscope slides**		A microscope slide is a thin flat piece of glass, typically 75 by 26 mm (3 by 1 inches) and about 1 mm thick, used to hold objects for examination under a microscope. Typically the object is mounted (secured) on the slide, and then both are inserted together in the microscope for viewing.
52.	**Microscope**		A light microscope is a biology laboratory instrument or tool, that uses visible light *to detect and magnify very small objects and enlarge them. They use lenses to focus light on the specimen, magnifying it thus producing an image. The specimen is normally placed close to the microscopic lens.* Steps on how to use a light microscope: Step 1: Connect the light microscope to a power source. Step 2: Turn the revolving nosepiece so the lowest objective lens is in position. Step 3: Mount your specimen onto the stage. Step 4: Use the metal clips to keep your slide in place. Step 5: Look into the eyepiece and slowly rotate the coarse adjustment knob to bring your specimen to focus. Step 6: Adjust the condenser for the maximum amount of light. Step 7: Now slowly rotate the fine adjustment knob until you obtain a clearer image of your specimen.

			Step 8: Examine your specimen. Step 9: After you're done viewing with the lowest power objective, switch to the medium power objective and re-adjust the focus with the fine adjustment knob. Step 10: Proceed to the high power objective once you have it focused.
53.	**Stirring rod**, glass, one end round, other flat, length 200 mm		A glass stirring rod is used *to stir or mix solutions. One of their main uses is to "scratch" the side of glassware (such as an Erlenmeyer Flask) to start the crystallization process in many experiments.*
54.	**Stopwatch.** 2 buttons with laps and 1/100 second functions. 12 hour setting, lcd count/ down/up		It is commonly used in laboratories, it can measure a time interval up to 0.01 second. It starts to indicate the time lapsed as the start/stop button is pressed. As soon as the start/stop button is pressed again, it stops and indicates the time interval recorded by it between the start and stop of an event.
55.	**Sweeping net** (muslin)insect nets, a light weight, robust insect net with 800mm long handle		Sweep nets are used to sweep through vegetation to collect random insects not easily seen

56.	**Tripod stands triangular top**, length of side arm 150 mm, height 200 mm, cast iron		A tripod is a portable three-legged frame or stand, used as a platform for supporting the weight and maintaining the stability of some other object. Ideal for the science laboratory or classroom to elevate Beakers or Flasks. They're perfect for use with Bunsen burners to support the object to be heated. Work best in conjunction with wire gauze mats.
57.	**Sets of permanent slides** (Transverse section (ts) of bronchioles, permanent slides with cover slip; Transverse section (ts) of veins, permanent slide with cover slip; Transverse section (ts) of artery, permanent slides with cover slip;Transverse section(ts) of kidney- (adrenal gland t.s. cortex and medulla) permanent slides with cover slip; Slides of the sense organs, permanent slides for different sense organs; Penicillium microscope slide; Prepared slide of urinary		A microscope slide is a thin flat piece of glass, typically 75 by 26 mm (3 by 1 inches) and about 1 mm thick, used to hold objects for examination under a microscope. Typically the object is permanently mounted (secured) on the slide, and then both are inserted together in the microscope for viewing. When using a microscope, slides that are permanent can be examined and stored for a long time, (Permanent slides must be properly made for successful long-term storage)

	system with slide cover; Prepared slide on mitosis, permanent slides with cover slip; Prepared slides of white blood cells, permanent slides with cover slip;Slides of neurons, sensory, motor and rely neurons; Ts leaf of dicotyledonous mesophyte (such as ligustrum or prunus or local equivalent), maize; Ts lungs to show alveoli permanent slides with cover slip;Ts ovule permanent slides with cover slip; Ts spinal cord, permanent slides with cover slip;Ts trachea permanent slides with cover slip; Nerve muscle junction, permanent slides covered with cover slip).		

II.2 List of biology chemicals

Nº	Name of chemical and quantities
1	Set of bottles as follows: Amylase enzyme - 1 lb (445g), trypsin/edta solution(100ml), protease (pack size: 500g), 1 for each sample: (Each set should contain 3 bottles, one for each type)
2	L -ascorbic acid (vitamin c) powder,100g
3	Benedict's solution,500ml
4	Sodium bicarbonate, 500g
5	Biuret reagent, laboratory grade, 100 ml
6	Bromothymol blue,500ml
7	2,6-dichloroindophenol is a dye used as a reagent in the determination of vitamin c. 1bottle
8	Eosin/red ink , dye content, ~99%,
9	Dextrose, monohydrate, powder, laboratory grade, 500 g
10	Iodine solution 2% in potassium iodide(aqueous), 30ml
11	Calcium hydroxide 500 g
12	Lugol's iodine solution 5% (1 oz.) Twin pack (2 bottles)
13	Methylated spirit (for extraction of chlorophyll),50ml
14	Methylene blue solution, 0.1% aqueous, laboratory grade, 500 ml
15	Millons' reagent ,500ml
16	Nutrient broth, 125ml
17	Agar powder , 100g
18	Potassium oxide, 250g
19	Starch 2%w/v solution 6.58, 500ml
20	Sucrose, molecular formula: c12h22o11, molecular weight: 342.30 (500g)
21	Toluidine blue stains for preparing slides to show mitosis,100g
22	Active dry yeast powder, 100g - lab grade chemical reagent
23	2,4-dinitrophenylhydrazine (brady's reagent),500g
24	Copper (II) carbonate, 250 g
25	Fehling's no1 copper solution,250 ml
26	Fehling's solution no 2, 250 ml
27	Distilled water, 25 l in high density, plastic container
28	Methyl orange sensitive,250ml
29	Sodium hydroxide pellets,250g
30	Hydrochloric acid, commercial, 500ml
31	Glucose,250g, pure solid cristals

PART III. EXPERIMENTS FOR S5

ACTIVITY 1.1: Observe predator-prey relationships in the environment

This activity can be done when teaching the concept or topic related to interspecific relationships among the organisms and their significance.

Rationale

The predator prey relationship consists of the interactions between two species and their consequent effects on each other. In the predator prey relationship, one species is feeding on the other species. The prey species is the animal being fed on, and the predator is the animal being fed. This activity of observing predator-prey relationships will enable us to explain relationships between organisms within their environment where even human beings depend on other organisms. This calls the human kind to be concerned with environmental protection for improvement of the health of the environment towards a balanced community of living organisms and non-living components in a particular environment.

Objective

To explain predator-prey relationships in the environment

Materials

- Computer
- Projector
- Internet connectivity
- Link for Video of predator-prey **relationships**

Experiment setup

Steps and procedure of the experiment

1. Connect projector to computer
2. Connect to internet to open the links: – https://www.youtube.com/watch?v=E5nfVsZcjDc
3. https://www.youtube.com/watch?v=CsfJL-IIVz4
4. https://www.youtube.com/watch?v=RtnLNmB3ZNE

Reflective questions:

- Why is predation important?
- Why do different predators have different preys?

Data recording

No	Predator Species	Prey Species	Observations
1	Lion	Zebra	Lions in few numbers are predators of zebras which are many in that environment.
2	Lion	Buffallo	Lions in few numbers are predators of buffaloes which are many in that environment.
3	Leopard	Hyena	Leopards in limited number are predator of hyena which are many in that environment.

Interpretation of results and conclusion

Predation is an interaction between the two species, i.e., predator and prey, in

which one species (predator) uses another species as food (prey). For example, in our video, the lion is a predator while the zebra is a prey.

In **predator-prey** relationships, the predator hunts other animals (prey) for their survival which will alternate the population size in the environment.

During our video watching, the observation is that as the predator population increases, it progressively consumes larger number of preys until the prey population starts to decline. Then the declining prey population no longer supports the large increasing predator population. As the prey population declines, the predator now faces a food shortage, and many of them starve or fail to reproduce.

However, the observed case is not common to all other ecological environment. For instance, in Akagera national part, observations show that, the predator population is less comparing to their prey population, hence there is no food shortage issue for predators. The interaction between predators and prey plays an important role in structuring ecological communities and provide stability for ecosystems.

Guidance on the evaluation

Assess learners on the significance of predator-prey relationship by asking some questions like:

Discuss the significance of predation in the ecosyst

UNIT: 2 TRANSPORT ACROSS THE CELL MEMBRANE

Experiment 2.1: Investigate simple diffusion in plant tissues and non-living materials using glucose solutions and visking tubing

This experiment can be done when teaching the concept or topic related to movement of substances across cell membrane.

Rationale

The internal environment of a cell is protected from the external environment by the cell or plasma membrane. The plasma membrane which is semi permeable governs or regulates the entry and exit of molecules or ions, most of the time based on their difference in concentration between the cell and its surroundings Such movement of substances is referred to as diffusion and plays an important role in living systems. For example, in the human body, many nutrients (in the form of ions and small molecules) enter the cells through diffusion . In plants, absorption and movement of water across the root is also done through the process of diffusion. Therefore, we need to investigate how simple diffusion of glucose solutions takes place using plant tissues and visking tubing

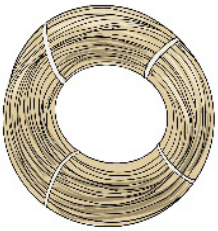
Objective

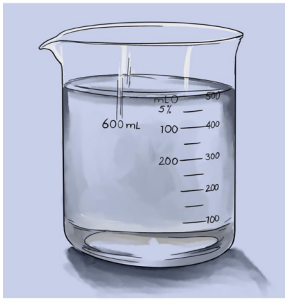
To investigate simple diffusion in plant tissues and non-living materials

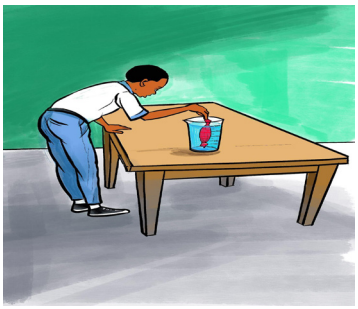
Materials

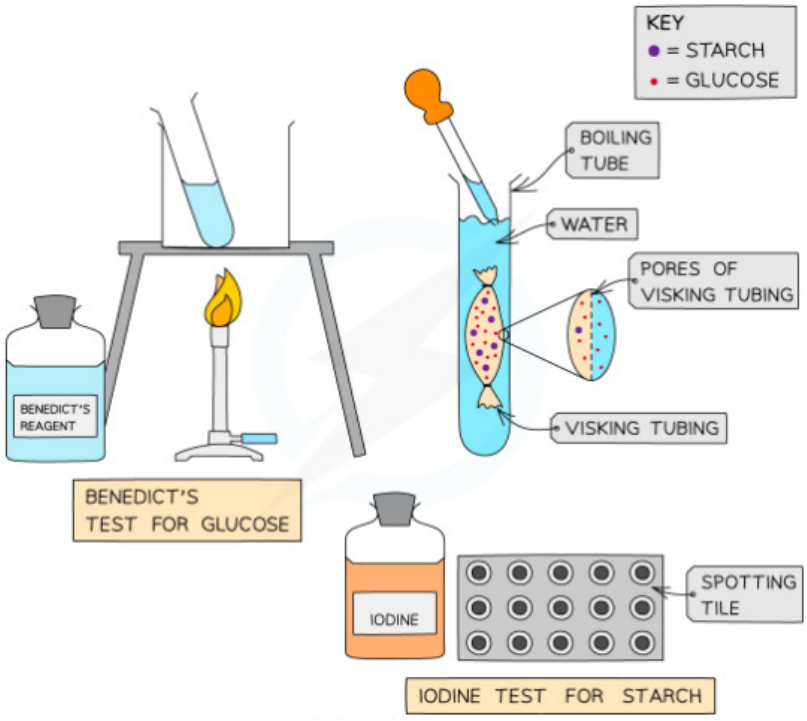
• Visking tubing Beaker • Starch • Beetroot • Iodine.	• Distilled water • Thread • Bunsen burner • Boiling tube	• Glucose • Retort stand • Benedict solution

Experiment setup









Procedure of the experiment

A) Beetroot and glucose

- Fill the visking tubing with glucose and beetroot solution.
- Fill a beaker with water.
- Soak the tubing in a beaker of water for 10 minutes
- Observe the diffusion of red solution from visking tubing into the water filled in the beaker

B) Starch and glucose

- Fill in a section of Visking tubing with a mixture of starch and glucose solutions
- Put water in a boiling tube
- Suspending the visking tubing in a boiling tube of water for a set period time
- Testing the water outside of the visking tubing at regular intervals for the presence of starch and glucose to monitor whether diffusion of either substance out of the tubing has occurred
- Record observation

Reflection question

What do you expect to happen after suspending the tubing in a boiling tube of water for a set period time?

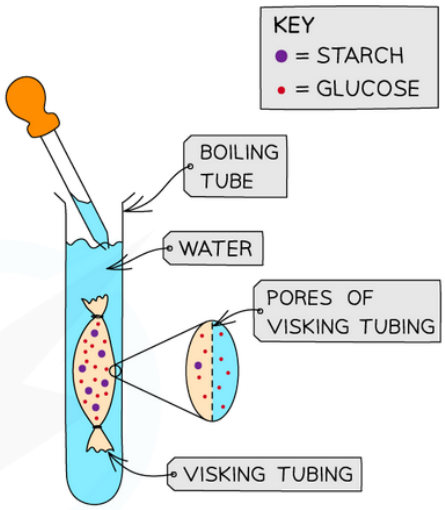
Data recording

Item	Observation (Color)
Beaker with water	Coulorless
Visking tubing	Coulorless
Starch	yellowish
Glucose	Coulorless
Beetroot	Red
Glucose - Beetroot solution	Red
Visking tubing with glucose-beetroot solution	Red

Visking tubing with solution glucose-beetroot into the water	Water changes in red color
Visking tubing with solution glucose-starch into the water	yellow to orange, brick –red color

Interpretation of results and conclusion

The water contained in the beaker changed the color to red due to movement of red pigment from the solution (Glucose-beetroot) in the visking tubing which is semi permeable. *The same process applies in plants and animal cells.*



The results of starch test and glucose test should indicate that glucose, but not starch, diffuses out of the visking tubing. The difference of diffusion of glucose and starch across the visiking tubules is done by testing for reducing sugar using benedict solution and by conducting test for starch. The results proved that, there is the presence of glucose in the water surrounding the visking tubules however not presence of starch. This was proved by the appearance of yellow to orange or brick –red color and the absence of blue-black color after performing the test for reducing sugar and test for starch. This tells that glucose diffused while starch did not.

Therefore, the solution of glucose and starch to observe the effect of a selectively permeable membrane on the diffusion of these molecules.

Visking tubing (dialysis tubing) is a non-living partially permeable membrane made from cellulose. Pores in this membrane are small enough to prevent the passage of large molecules (such as starch and sucrose) but allow smaller molecules (such as glucose) to pass through by diffusion (concentration gradients and membrane permeability).

Source of error

- Not tie both ends of the visking tubing firmly,
- Allow the open end of the visking tubing to fall into the beaker.

Guidance on the evaluation

Assess learners by focusing on diffusion in living things and non-living things. You can ask them to discuss on the difference between diffusion in plant tissue non-living materials using glucose solutions and visking tubing

Provide learners with materials and request them to perform the same activity

Experiment 2.2: Investigate effects of solutions of different water potentials on immersing plant tissue

This experiment can be done when teaching the concept or topic related to osmosis

Rationale

Living cells of both plants and animals are enclosed by a partially-permeable membrane called the cell membrane, which regulates the flow of liquids and of dissolved solids and gases into and out of the cell. Plant roots absorb water and minerals from soil and take it upwards to the leaves and other plant parts which are essential for plant growth. This is known as osmosis. The osmosis is of prime importance in living organism, For instance, nutrients are distributed within the body and metabolic waste products released via osmosis.

Objective

To investigate the effects of solutions of different water potentials on immersing plant tissue

Materials

- Irish potato tissue
- Salt (solute)
- Water
- Beakers
- Cork borer
- Knife
- Meter ruler

Experiment setup

Beaker A (isotonic) **Beaker B (Hypo)** **Beaker C (Hyper)**

Figure: Investigating the effects of immersing plant tissue in solutions of different water potentials

Procedure of the experiment

1. Set three beakers A, B and C with different salt concentrations (Isotonic, Hypotonic and Hypertonic solutions)
2. Place potato cylinders in all the beakers A, B and C
3. Leave the set ups uninterrupted for 45 minutes
4. Work out the change in length of the potato size in the three beakers

Data recording

Beakers	Initial length	Final length	Observed changes
Beaker A (Isotonic solution)	6mm	6mm	No change in potato size
Beaker B (Hypotonic solution)	6mm	>6mm	Potato size increases
Beaker C (Hypertonic solution)	6mm	<6mm	Potato size decreases

Figure: *Investigating the effects of immersing plant tissue in solutions of different water potentials*

Interpretation of results and conclusion

- In hypertonic medium with respect to the potato tissue cylinder, i.e., with higher solute concentration than the cell interior, water moved out of the cell into the medium. This what caused the potato cylinder to shrink in size.
- In the hypotonic medium with respect to the potato tissue cylinder, i.e., the concentration of solute in the cytosol is higher than that of the solution. In this condition, water diffuses into the cell due to osmotic pressure and the potato tissue cylinder becomes turgid, or bloated.
- In isotonic medium with respect to the potato tissue cylinder, i.e., the solute concentration is equal to that in the cell, the net movement of water across the membrane is zero. The potato tissue cylinder and concentration remained constant.

So, water moved from the medium with high water potential to the medium with low water potential until the medium is equilibrated which has led to changes in the size of the cell.

Guidance on the evaluation

Assess learners on the effects of solutions of different water potentials on immersing plant tissue (Osmosis) using another immersing plant tissue and request them to record data and interpret them.

UNIT: 3 CHROMOSOMES AND NUCLEIC ACIDS

Activity 3.1: Use microscopic slides of prophase during mitosis to draw a typical observed structure of a chromosome

This activity can be done when teaching the concept or topic related to the structure of chromosomes during the process of cell division

Rationale

Prophase is the first stage in mitotic division. During this phase of cell division, DNA is folded into chromosomes. Thread-like structure of chromosomes is seen under the compound microscope. The chromosome is responsible for carrying all genetic information contained in DNA. This activity will allow us to explore the structure of chromosomes during the mitotic phase and understand the role of cell division in organisms' growth.

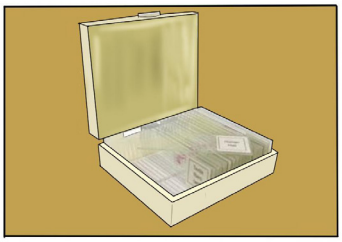
Objective

To draw chromosome structure in the prophase stage of mitosis.

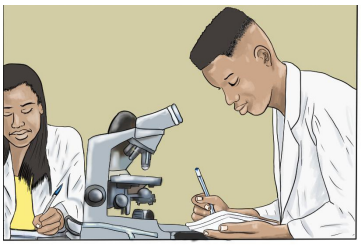
Materials

- Permanent slide of prophase stage of mitotic cell division
- Compound microscope
- Pencil and rubber
- Paper

Experiment setup



1



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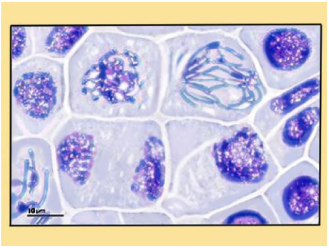
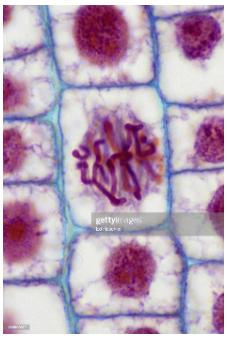


3

Procedure of the experiment

1. Take a permanent slide of prophase stage of mitotic cell division.
2. Place it on the stage of the compound microscope.
3. Adjust the microscope following the procedures of using the compound microscope.
4. Observe the prophase stage of mitotic cell division.
5. Draw the image observed under the compound microscope.

Data recording

Mitosis process	
step	Observations
1	 • Chromosomes are visible • Nucleolus envelop breaks down • Nucleolus not visible

Interpretation of results and conclusion

Prophase is the first phase of mitosis, the process that separates the duplicated genetic material carried in the nucleus of a parent cell into two identical daughter cells. During prophase, the complex of DNA and proteins contained in the nucleus, known as chromatin, condenses into chromosomes, cell nucleolus disappear and meiotic spindle is formed.

As it is observed, in prophase chromosomes become more tightly coiled, chromatids condense into discrete chromosome, and each chromosome consisting of two sister chromatids can be seen.

Source of errors

- Using uncleaned permanent slides
- Not respecting the procedures and steps while using compound microscope

Guidance on the evaluation

Assess learners on chromosome structure as observed in prophase stage. Ask questions like:

1. What are the main observed parts of chromosomes under microscope at the prophase stage?
2. What can you say about the nuclear membrane and spindle fibers in the prophase stage observed under a microscope?

Experiment 5.1: Investigating the time spent by the cells of onion root tips during each stage of mitosis

This activity can be done when teaching the concept or topic related to cell division.

Rationale

All somatic cells of an organism's body divide by mitosis, a process consisting of different consecutive stages. With mitosis, a single cell divides into two identical daughter cells, leading to the organism's growth. This activity will allow us to explore cell division in plants and understand that different stages of cell division last different times in different organisms. This also explains why different organisms may grow at different rates.

Objective

To identify cells' changes during mitotic cell division

Materials

- Permanent slides of onion root tip cells at different stages of mitosis
- Compound microscope

Experiment setup

Procedure of the experiment

1. Turn on the microscope and put an onion root tip cells sample slide on the stage
2. Adjust the lens until image is focussed
3. Count the total number of cells in the view and record the number
4. Count the number of cells in interphase and record the number
5. Repeat step 4 with cells in prophase, metaphase, anaphase, and telophase
6. Move slide around to a new view (keeping view in the root tip region) and repeat steps 4 and 5 again.
7. Use the following formula to calculate the time spent by each cell at a given stage of mitosis

Data recording

N°	Stage of mitosis	Number of cells as observed under microscope	Time taken by a phase in minute
1	Interphase	10	267
2	Prophase	6	160
3	Metaphase	5	133
4	Anaphase	4	107
5	Telophase	2	53
Total		27	720

Interpretation of results and conclusion

Interphase and Mitosis occur in every eukaryotic cell, including onion cells. Interphase is the process in which cells grow and replicate their DNA, and cells spend most of their life in this stage. During mitosis, which occurs in 4 main stages (Prophase, Metaphase, Anaphase, and Telophase), a cell divides into 2 identical daughter cells. The cells of root tips grow continuously and this implies the constant interphase and mitosis. In this activity, the cells of onion root tip were examined under a microscope. He total number of cells viewed at each stage were recorded. The percentage of cells in each stage compared to the total number of cells is related to the amount of time spent by cells at each phase of the cell cycle.

Source of errors

- Using uncleaned permanent slides
- Not respecting the procedures and steps of using compound microscope

Guidance on the evaluation

Assess learners on mitosis in plant cells. Ask some questions like:

1. Which changes observed at each stage of mitosis?
2. Which is the longest stage of mitotic division?

Experiment 5.2: Examine prepared slides of dividing plant root tip cells of onion and animal cheek cells and outline how dividing animal cells are different from dividing plant cells

This activity will be done when teaching the concept or topic related to cell and nuclear division.

Rationale

Animal and plant cells are different from each other. Their differences are even remarkable during the different phases of cell division. This activity will allow learners to explore the differences between the dividing plant and animal cells throughout the stages of cell division.

Objective

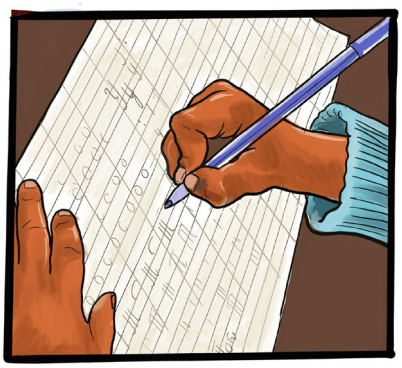
To differentiate the animal cell (cheek cells) from plant cells (onion root tip) throughout stages of cell division.

Materials

1. Prepared slides of onion root tip cells at different stages of cell division
2. Prepared slides of cheek cells at different stages of cell division
3. Compound microscope

Experiment setup

Observing onion and cheek cells



Recording the observations

Procedure of the experiment

1. Turn on the microscope and put an onion root permanent slide on the stage .
2. Adjust the microscope until image is in focussed.
3. Observe the cell.
4. Repeat the step one, two and three for cheek cells
5. Record the difference between onion root tip cells and human cheek cells.

Reflective question

What are similarities and differences observed between dividing animal and plant cells throughout the stages of cell division?

Data recording

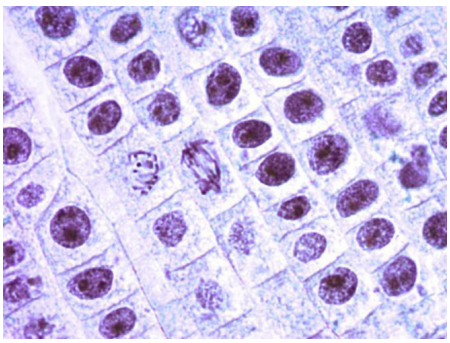


Figure1: Image of onion root tip cells

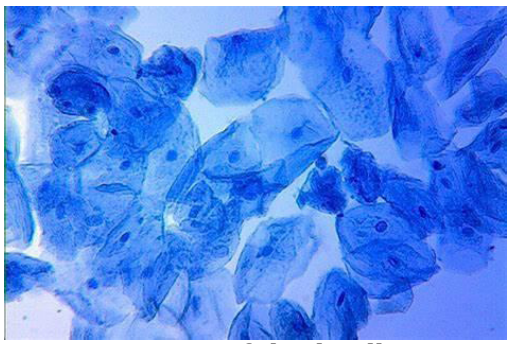


Figure 2: Image of cheek cells

Features	Animal Cell (cheek cell)	Plant Cell (onion root tip cell)
Cell Shape	Round (irregular shape)	Rectangular (fixed shape)
Cell Wall	Absent	Present and is formed of cellulose
Cell Membrane	Present	Present and is covered by the cell wall
Nucleus	Present	Present
Vacuole	One or more small vacuoles	A large central vacuole taking up 90% of the cell volume
Mitochondria	Present	Present

Interpretation of results and conclusion

An onion is a multicellular plant organism. As in all plant cells, the cell of an onion peel consists of a cell wall, cell membrane, cytoplasm, nucleus and a large vacuole. The nucleus is present at the periphery of the cytoplasm. The vacuole is prominent and present at the centre of the cell. It is surrounded by cytoplasm. The presence of a cell wall and a large vacuole are indicators that help identify plant cells, such as seen in the onion peel.

As in all animal cells, the cells of the human cheek do not possess a cell wall. A cell membrane that is semi-permeable surrounds the cytoplasm. Unlike plant cells, the cytoplasm in an animal cell is denser, granular and occupies a larger space. The vacuole in an animal cell is smaller in size, or absent. The nucleus is present at the centre of the cytoplasm. The absence of a cell wall together with a prominent vacuole are indicators that help identify animal cells and to distinguish it with plant cell.

Comparison between onion root tip cell and cheek cell

Features	Animal Cell (cheek cell)	Plant Cell (onion root tip cell)
Cell Shape	Round (irregular shape)	Rectangular (fixed shape)
Cell Wall	Absent	Present and is formed of cellulose
Cell Membrane	Present	Present and is covered by the cell wall
Nucleus	Present	Present
Vacuole	One or more small vacuoles	A large central vacuole taking up 90% of the cell volume
Plastids	Present	Present
Chloroplast	Absent	Present and make their own food
Endoplasmic Reticulum	Present	Present
Ribosomes	Present	Present
Mitochondria	Present	Present

Source of errors

- Using uncleaned permanent slides
- Not respecting the procedures and steps of using compound microscope

Guidance on the evaluation

Assess the learners on major differences between the dividing animal and plant cells at the different stages of cell division.

Ask some questions like:

- What are the plant cell parts not found in animal cell and why?
- Why do we find larger vacuole in plant cells more than in animal cells?

UNIT: 7 AUTOTROPHIC NUTRITION

Experiment 7.1: Carry out tests for starch in terrestrial plants

This activity can be done when teaching the concept or topic related to autotrophic nutrition, precisely the topic of test for starch which is an important result of photosynthesis in terrestrial plants.

Rationale

All organisms require macromolecules like carbohydrates, proteins and fats for their growth and development. Some organisms mostly plants produce these organic compounds from inorganic sources on their own, in a process known as photosynthesis and those organisms are called autotrophs. During photosynthesis, the food produced by plants is in the form of carbohydrates (starch). This experiment aims at testing the presence of starch in the leaves of terrestrial plants and will allow learners to know that starch is a result of photosynthesis.

Objective

To investigate the presence of starch in terrestrial plants.

Materials

• Bunsen burner, • Wire gauze • Boiling tubes (Test tubes) • Test tube holder • Two potted plants • 90% ethanol or ethyl alcohol • Iodine solution	• Tripod stand, • 250 cm^3 beakers (2) • Forceps • White tile or petri dishes • 90% ethanol or ethyl alcohol • Droppers

Experiment setup

Tests for starch in terrestrial plants (https://www.dreamstime.com/leaf-starch-test-school-scientific-experiment-proves-photosynthesis-leaves-boiling-water-ethanol-washing-reaction-iodine-image156947837)

Procedure of the experiment

1. Take two potted plants. Keep one in dark and other in well illuminated conditions.
2. After 24 hours , take leaves from each plant
3. Half-fill two 250 cm^3 beakers with water. Heat the water until it boils. Keep the water at boiling point.
4. Use the forceps to place these leaves separately in the boiling water. Boil for 2 minutes.
5. Turn off the bunsen burner. (If you are using a heat source without a naked flame - electric water bath or hot plate - this step is unnecessary.)
6. Place the boiled leaves in two different boiling tubes containing 90% ethanol or ethyl alcohol
7. Place the boiling tube in a beaker containing hot water and boil for 10 minutes or until the leaves decolorize (It may be necessary to replace the ethanol).
8. Gently remove the leaves and wash with a fine trickle of cold tap water.
9. Separately spread the leaves evenly on a white tile or a petri dish.
10. Add a few drops of iodine and note your observation

Reflection questions

1. What was the effect of putting one leaf in dark and another in well illuminated conditions?
2. What was the effect of boiling the leaf in water?
3. What made leaves turn blue-black?

Data recording

Specimen	Colour	In boiling alcohol	Addition of iodine
Illuminated leaf	Green	Green colour disappears	Blue black
Covered/not illuminated leaf	Green	Green colour disappears	Reddish brown

Interpretation of results and conclusion

During this experiment, leaves were placed in hot water and ethanol. The hot water softens the leaf and the alcohol breaks down the chlorophyll, taking the green color out of the leaf. When you put iodine on the leaves, one of them will turn blue-black and the other will be a reddish-brown. Iodine is an indicator that turns blue-black in the presence of starch. The leaf that was in the light turns blue-black, which demonstrates that the leaf has been performing photosynthesis and producing starch. The leaf that was covered turns into reddish-brown, which demonstrates that there was no remaining starch since it was not performing photosynthesis as the other one. This proves that the starch is a result of photosynthesis in terrestrial plants.

Guidance on the evaluation

Try the test again with a variegated leaf (one with both green and white) that has been in the sunlight.

Assess learners on photosynthesis by asking questions such as:

- A leaf needs chlorophyll to perform photosynthesis. Based on that information, where on the variegated leaf will you find starch?

Experiment 7.2: Carry out tests for oxygen in aquatic plants

This experiment can be done when teaching the concept or topic related to autotrophic nutrition precisely the topic of test for oxygen in aquatic plants.

Rationale

Autotrophic nutrition means self-nutrition. Most autotrophs use a process called photosynthesis to make their food. In photosynthesis, autotrophs use energy from the sun to convert water from the soil and carbon dioxide from the air into a nutrient called glucose. Plants, including aquatic plants, produce oxygen. The Elodea genus is composed of aquatic plant species known for their excellent oxygenating properties. Those plants are recommended for demonstrating the formation of oxygen during photosynthesis. This experiment will allow learners to know that even aquatic plants produce oxygen during photosynthesis.

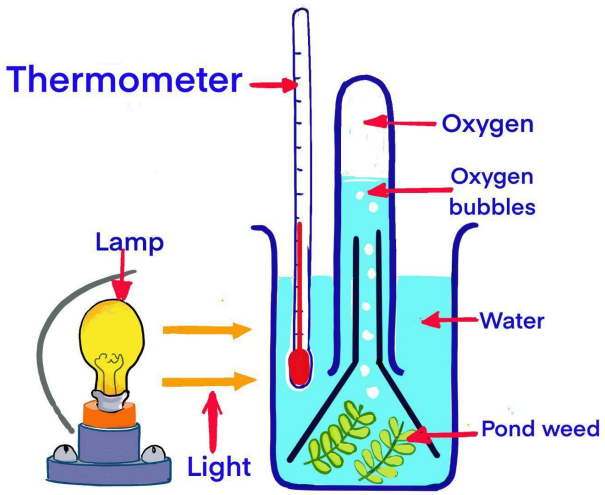
Objective

To demonstrate that oxygen is produced by aquatic plants during photosynthesis

Materials

• Aquatic Plant/Algae • 1 g Sodium Bicarbonate • Large Funnel (must fit into the large container upside down) • Rubber Band • Dechlorinated Tap Water	• Large, Clear Container • Stirring Rod • Test Tube (must fit inside the stem of the funnel) • 20-W Fluorescent Light Source (sunlight) • Scissors

Experiment setup



Procedure of the experiment

1. Fill the large, clear container at 3/4 full with the dechlorinated tap water at room-temperature .
2. Add 1 g of sodium bicarbonate to the water and stir until dissolved.
3. Cut 8 to 12 sprigs of the plant to a length of about 20 cm.
4. Place the cut sprigs into the mouth of the funnel.
5. Invert the funnel and place it into the container of water, trapping the aquatic plant inside the funnel.
6. Make sure the stem of the funnel is completely submerged in the water. If it's not, add more dechlorinated water to the container until the funnel stem is covered.
7. Wrap a rubber band about 1/4 of the way down the test tube several times. This allows the test tube to sit inside the stem of the funnel without falling all the way into it.
8. Submerge the test tube into water in the container, filling it completely.
9. Invert the test tube in the water and place it over the stem of the funnel while it is still submerged. Make sure no air bubbles are trapped in the test tube.
10. Place a fluorescent light source near the container and turn it on.
11. Leave this setup undisturbed for 24 hours.
12. Observe the oxygen that is trapped in the test tube after 24 hours.

Precautions

- Add enough sodium bicarbonate
- Carry out the experiment in illuminated condition.

Reflection questions

1. Why are aquatic plants used in this experiment?
2. Why do we use $NaHCO_3$ in water during this experiment?

Data recording

Activity	Observations
Inverting the test tube on the stem of the funnel while it is still submerged	Air bubbles move at the upper end of the test tube.
Keeping the inverted test tube more time	Some gas collected at the top of the inverted test tube and a downward displacement of water.
Rapid introduction of glowing splinter in the collected gas in the test tube	A flame on glowing splinter

Interpretation of results and conclusion

In water, sodium bicarbonate serves as the source of CO_2 used by the plant. Sodium bicarbonate is added in water to provide more carbon dioxide necessary for photosynthesis to take place.

As oxygen is produced through photosynthesis, it travels up the stem of the funnel into the test tube where it displaces the water. The assembly was then exposed to sunlight for 5 hours. While exposed, the plants produced a gas which was collected in the inverted test tube. After the production of enough gas, the test tube was removed, inverted, and a glowing piece of wood was inserted into the tube. The glowing wood was observed to burn more rapidly in the gas in the test tube than in ordinary air. The glowing splint has confirmed that that air was oxygen.

Source of errors

- No or less $NaHCO_{3,}$ that can cause the absence of required carbon dioxide for the reaction to take place.
- No or less light to allow photosynthesis

Guidance on the evaluation

Assess learners on the formation of oxygen by photosynthesis in plants . Ask questions like:

1. What does the more and rapid burning of wood introduced in the test tube mean?

Experiment 7.3: Investigating the effects limiting factors on the rate of photosynthesis

This experiment can be carried out when teaching the concept or topic related to autotrophic nutrition especially when teaching the limiting factors on the rate of photosynthesis.

Rationale

The rate of photosynthesis depends on a number of environmental factors. The limiting factors are conditions that when in shortage, slow down the rate of a reaction. Light intensity, carbon dioxide concentration and temperature are limiting factors for the rate of photosynthesis. Investigations of the effects of those limiting factors can help in appropriate control of photosynthesis which is important process in plants in producing their foods also needed by other living organisms.

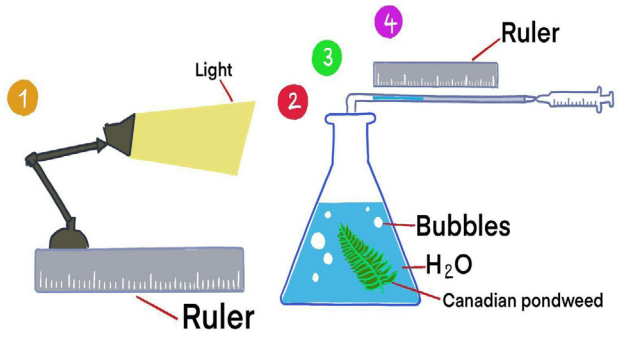
Objective

To investigate the effect of varying light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis.

Materials

• Distilled water • Erlenmeyer • Beaker • Aquatic plant (algae or algal beads) • Sodium hydrogen carbonate solution • Test tube plug/ Rubber stoppers • Water bath • Glass tank	• Test tube • Glass delivery tube • Lamp • Ruler • Thermometer • Gas syringe • Stop watch

Experiment setup



Source: https://studymind.co.uk/notes/limiting-factors-affecting-the-rate-of-photosynthesis/

This setup can be also seen separately as following:

Fugure: Investigating effect of light intensity

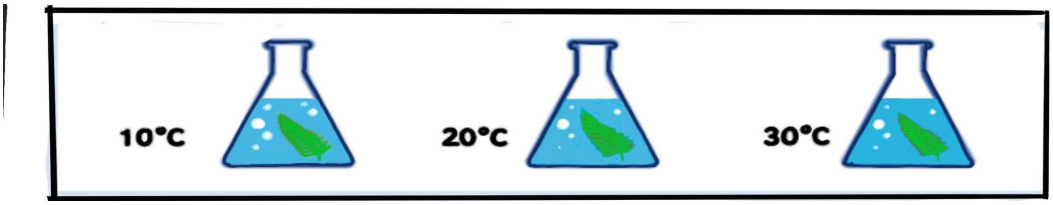


Figure: Investigating effect of temperature

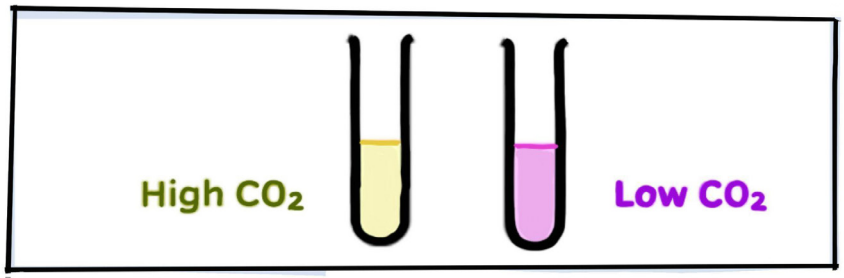


Figure: Investigating the effect of CO2 by varying amounts of sodium hydrogen-carbonate in the boiling tube

Procedure of the experiment

1. Ensure that water is well aerated before using by bubbling air through it. (This will ensure oxygen gas given off by the plant during the investigation form bubbles and do not dissolve in water).
2. Ensure that the plant has been well illuminated before use. (This will ensure that the plant contains all the enzymes required for photosynthesis and that any changes of the rate are due to the independent variable)
3. Set up the apparatus in a darkened room
4. Ensure that the pondweed is submerged in sodium hydrogen carbonate solution (1%) (this ensures the controlled supply of carbon dioxide for the pondweed)
5. Cut the stem of the pondweed cleanly just before placing it into the test tube
6. Measure the volume of gas collected in the gas-syringe in a set period of time (eg. 5 minutes)
7. Change the independent variable (ie. change the light intensity, carbon dioxide concentration or temperature depending on which limiting factor you are investigating)
8. Place the lamp at distance d of 0.1 m, 0.5m, 0.25m, 0.125m, within 1 minute for each step.
9. Record the results in a table and plot a graph of volume of oxygen produced per minute against the distance from the lamp (if investigating light intensity), carbon dioxide concentration, or temperature.

Note: For changing the CO_2 concentration, we shall need to gradually add the quantity of bicarbonate ($NaHCO_3$) while for temperature we shall have to set the water bath at the desired level.

Data recording

The recorded data may change due to different working conditions. When you change an independent variable (light intensity, temperature, and amount of $NaHCO_3$) you will record the different number of bubbles or volumes of oxygen produced.

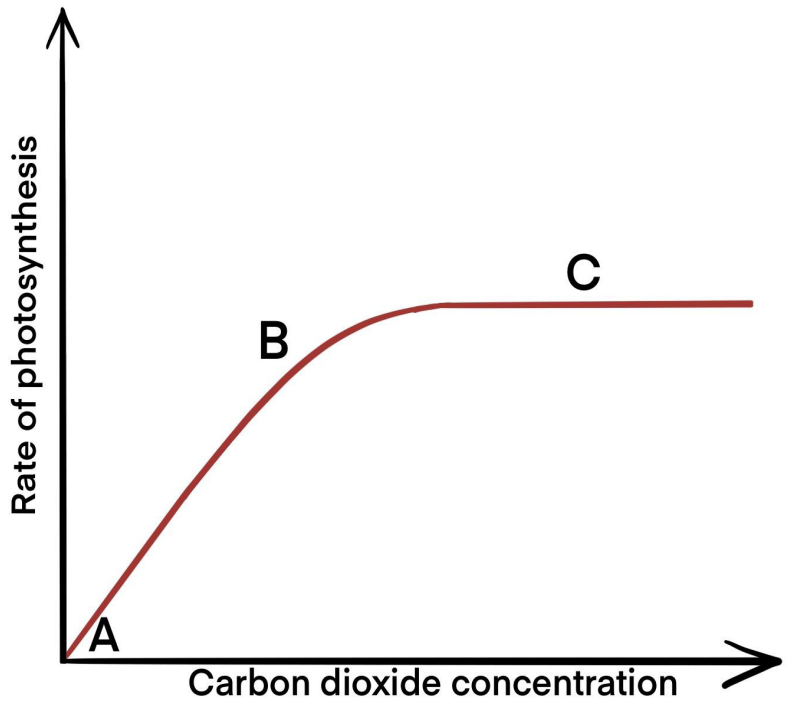
Light intensity vs Photosynthesis rate

Distance (m) from lamp in 5 min	Number of bubbles given off in 1 min
0.1	8
0.5	28
0.25	105
0.125	105

Graph: The results by placing light intensity on the x-axis.

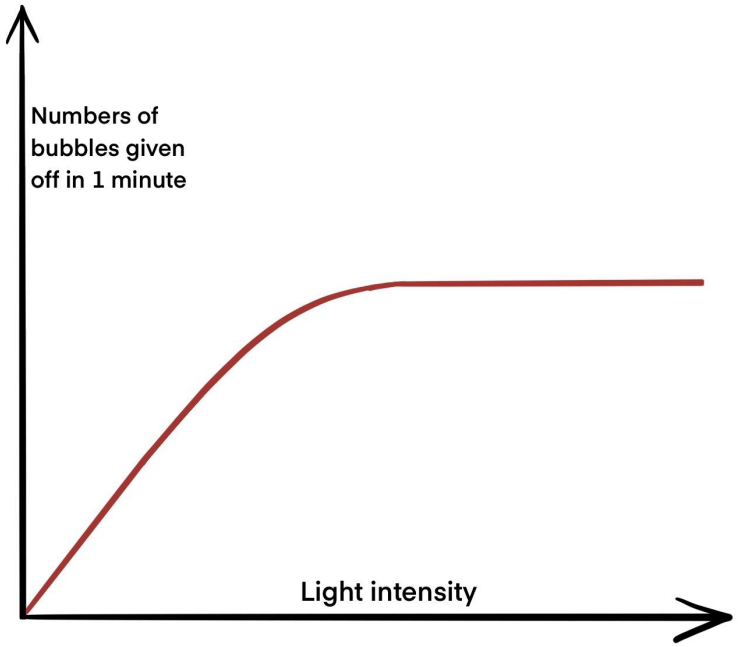
Table of CO_2 vs photosynthesis rate

Amount of $NaHCO_3$ (g)	Number of bubbles given off in 1min (Volume of oxygen produced)
0.2	6
0.25	8
0.5	12
0.75	20
1	20

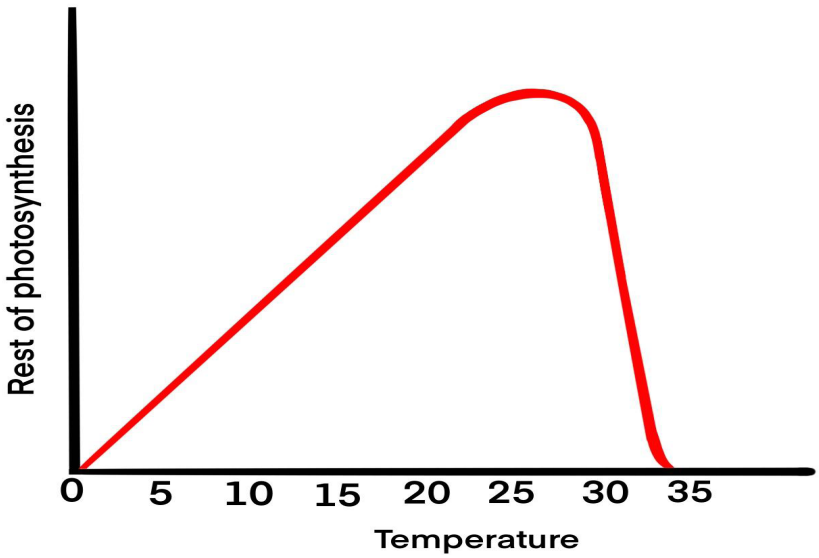


Graph: *Effect of carbon dioxide on the rate of photosynthesis*

Temperature (^{o}C)	Number of bubbles given off in 1min
10	6
20	14
30	50



Temperature vs. Photosynthesis



Graph: *Effect of temperature on photosynthesis rate*

Interpretation of results and conclusion

Investigations to determine the effects of light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis can be carried out using aquatic plants, such as *Elodea* or Cabomba (types of pondweeds). The effect of these limiting factors on the rate of photosynthesis can be investigated in the following ways:

Light intensity: Increasing the light intensity will boost the speed of photosynthesis. However, at high light intensities the rate becomes constant.

Carbon dioxide concentration: by adding different quantities of sodium bicarbonate ($NaHCO_3$) to the water surrounding the plant, this dissolves to produce CO_2 that is being used by the plant to photosynthesize.

Temperature (of the solution surrounding the plant): Placing the boiling tube containing the submerged plant in water baths of different temperatures showed that temperature has an impact on the rate of photosynthesis. The rate of photosynthesis increases as the temperature rises. During photosynthesis, a temperature of more than 40 °C slows down the process as enzymes involved in photosynthesis get denaturated from that temperature..

Changing one of these factors during the investigation (as described above), ensures the other two remain constant. For example, when investigating the effect of light intensity on the rate of photosynthesis, a glass tank should be placed in between the lamp and the boiling tube containing the pondweed to absorb heat from the lamp – this prevents the solution surrounding the plant from changing temperature. As a varying factor increases, photosynthesis rate increases in terms of the number of bubbles observed. This setup is carried out in a dark room to control the light intensity.

Note on source of errors

- Set up not conducted in a dark room.
- Changing variables at the same time will confuse learners to know the effect of each factor. Changing one of the factors during the investigation (to ensure the other two remain constant).
- Not submerging pondweed in sodium hydrogen carbonate solution (1%). This will lead to the absence of CO_2 and hinder photosynthesis .

Guidance on the evaluation

Ask learners to discuss the effect of each factor on photosynthesis rate.

Experiment 7.4: To use chromatography to separate chloroplast pigments from different plants.

This activity can be done when teaching the concept or topic related to autotrophic nutrition, mainly the chloroplast pigments involved in photosynthesis in different plants.

Rationale

A pigment is a substance that absorbs light of different wavelengths. They are involved in absorption of light of a certain wavelength. The absorbed wavelength of light has the correct energy to excite specific transitions of electrons in the pigments. Photosynthesis depends on light absorption by pigments in leaves. This experiment aims at distinguishing and studying the various pigments present in plants through the process of paper chromatography.

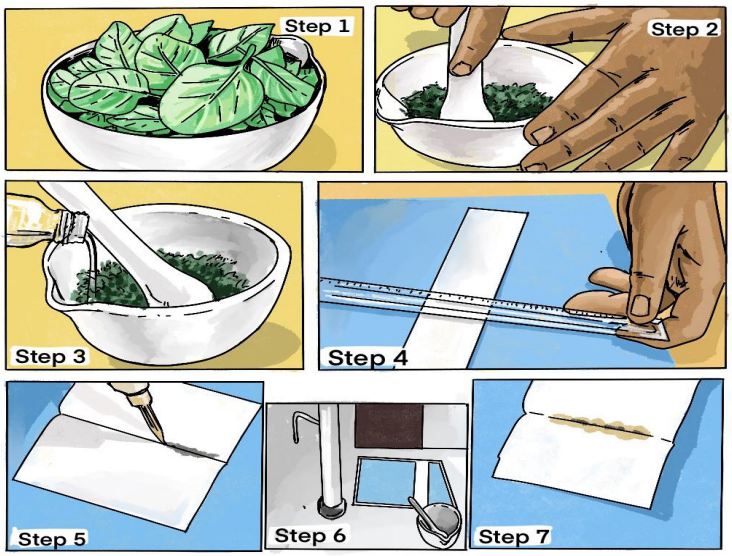
Objective

To separate chloroplast pigments in different collected plants' leaves by using chromotography.

Materials

• Chromatography chamber • Mortar and pestle • Ether acetone solvent • Capillary tube • Spatula	• Plant leaves (Spinach,…) • Scissors • Acetone • Pencil • Filter paper strips

Experiment setup



https://www.youtube.com/watch?v=W56RHxu2Hpc

Procedure of the experiment

1. Cut a vertical strip (10 cm) × (2.5 cm) of Whatmann's filter paper No.1.
2. Make it V-shaped at one end.
3. Draw a horizontal line with a pencil (not pen) about half an inch from the bottom.
4. Make leaf extract by crushing 20 g leaves in 20 mL acetone.
5. With the help of a capillary tube, load a small drop of leaf extract at the center of the pencil mark and air dry.
6. Repeat the previous step for 5-6 times.
7. Insert paper strips in a chromatographic chamber pre-saturated with Ether acetone solvent such that only the tip of the paper is dipped into the solvent.
8. Do not dip the loaded pigment into solvent.
9. Allow it to run for few (1-2) hours.
10. Take out strips and mark solvent front and different coloured separated pigments.

Reflection questions

1. What is the role of pigment substances in a plant's leaf?
2. What do the different bands formed on your filter paper mean?

Data recording

The dried paper strip displays four different bands. Discrete pigments can be distinguished with the help of colors.

Bands on paper	Color observed
Band A	Dark green
Band B	Yellowish-green
Band C	Yellow
Band D	Orange

Interpretation of results and conclusion

Pigments are involved in absorption of light of a certain wavelength. While some wavelengths are absorbed, others are reflected or scattered, which imparts them color. Photosynthesis can be carried out in isolated chloroplast but not in isolated pigments. The Carotene pigment is observed at the topmost as an orange-yellow band of pigments distinctively, while below it, there is a yellowish band which indicates the pigment xanthophyll. Then, the third band appearing dark green indicates chlorophyll-a pigment, and the yellowish-green band present at the bottom is the chlorophyll pigment.

Source of errors

1. Too much addition of solvents can make the cru shed sample more diluted, hence, leads to less effective results.
2. Selected leaves not green and fresh to get the desired results.

Guidance on the evaluation

1. Write a short note on how you can use the paper chromatography to identify the chloroplast pigments in plants' leaves?
2. Assess the significance of pigment substances on the plant's leaf.

Experiment 7.5: Investigate the effect of light intensity or light wavelength on the rate of photosynthesis using a redox indicator

This experiment can be done when teaching the concept or topic related to the effect of light intensity on the rate of photosynthesis.

Rationale

The process of photosynthesis takes place in two major phases which are light-dependent and the light-independent stage which are interdependent phases. Redox indicators are a type of chemical added to a solution, and when this solution is reduced or oxidized (reaction where electrons are both lost and gained), the redox indicator suddenly changes its colour. For instance, the oxidized DCPIP is blue in colour and the reduced DCPIP is colourless. Hence, accepting the electron makes it change its colour. Because of the green colour of the chlorophyll, the colour of the reduced solution may appear green. The rate at which the redox indicator alters its colour from its oxidized form to its reduced form can be employed to determine the rate of photosynthesis. In the presence of higher intensity light or preferable wavelengths of light, there is a rapid rate of photoactivation of an electron. Hence, the rate of reduction of the indicator is also quicker.

This experiment will allow learners to investigate the effect of light intensity on the rate of photosynthesis using a redox indicator.

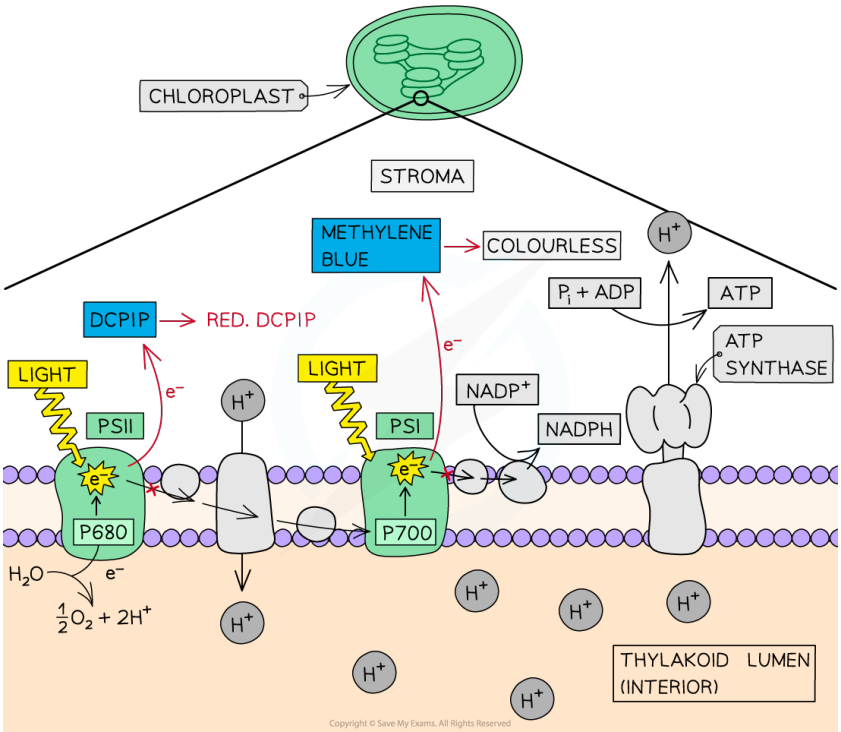
Objective

To investigate the effect of light intensity on the rate of photosynthesis using a redox indicator.

Materials

• Plant leaves • Source of light • DCPIP or methylene blue • Pestle • Funnel • Stopwatch • Centrifuge	• Water bath • Test tubes • Mortar • Muslin cloth • Beaker • Pipette • Cold isolation medium at ice level (made up of phosphate buffer solution, sucrose and potassium chloride)

Experiment setup



Procedure of the experiment

1. Crush the leaves using pestle and mortar with about 20 cm^3 of the isolation medium
2. Place the four layers of muslin cloth into the funnel and gently wet them with the cold isolation medium
3. Place the funnel above the beaker
4. Filter the mixture of the crushed leaves
5. Pour the solution in the funnel into the centrifuge tubes, making sure that each tube contains same amount of solution,
6. Centrifuge the tubes for around 10 minutes at high speed to produce a small pellet of leaf extract
7. Pour off the extra liquid that surrounds the pellet and resuspend the pellet with around 2cm^3 of the isolation medium
8. In each test tube, add 0.5 cm^3 of the new leaf extract solution
9. Add 5 cm^3 of DCPIP or methylene blue indicator into each test tube
10. Place each test tube into a separate dark room with a single LED light(make sure to place one test tube in entirely dark room as a control)
11. Vary the distance of the LED light from the test tube
12. Stir each test tube and note down the time it takes for the solution to decolourise
13. Note the color change

Reflective questions

1. How does light intensity affect the rate of photosynthesis?
2. What change do you expect to observe when using a redox indicator on leave solution?

Data recording

Solutions in tubes	*Observations*
Exposed to light	Color changes from blue to green
In dark room	Solution remains blue

Interpretation of results and conclusion

The light dependent reactions of photosynthesis take place in the plant cell's chloroplasts.

During photosynthesis, chlorophyll absorbs photons which are a type of light energy. In this experiment we used a redox indicator that replaced the electron acceptor and becomes colorless. When reduced, it allows any reducing agent produced by the chloroplast to be detected and then results in the observed color change of the solution from blue to green.

For the tubes in the dark room, there was no color change due to the absence of light, therefore no photosynthesis occurred.

Guidance on the evaluation

Discuss the process of photosynthesis under the following conditions:

a. At very low light level
b. As the light intensity increases
c. At high light intensities

UNIT: 8 TRANSPORT IN PLANTS

Experiment 8.1: Show the transport structures in stem and roots

This experiment can be done in teaching the concept or topic related to transport structures in plants.

Rationale

Plants have a unique mechanism for transport of water and nutrients. Water is taken up by the roots and transported along with minerals to other parts of the plant. Along with water, many nutrient elements that are essential for the growth of the plants are also taken up from the soil. Plants use two different transport systems, both made up of rows of cells forming tubes throughout the plant. The xylem transports water and minerals from the roots to the leaves while the phloem moves food substances from leaves to the rest of the plant.

Objective

To show the transport structures in stem and roots

Materials

- A fresh green plant
- Glass of water
- Natural food colour
- Razor
- Slide
- Light microscope

Experiment setup

Procedure of the experiment

1. Dig out a small tomato plant.
2. Cut the stem at the base 1 to 2 cm above roots under water.
3. Pour eosin solution into a beaker
4. Immerse the cut end in an eosin solution contained in a beaker.
5. Fix the shoot erect with the help of a stand.
6. Keep it for a day or two without disturbing it.
7. Cut the transverse sections of that stem to get a thin membrane
8. Put the sample on a slide
9. Observe it under the microscope.

Reflection questions

1. Before you observe the transverse section of the stem under the microscope, what do you think the stem will look like?
2. Explain why some part of the stem appears coloured.

Data recording

Sample (Small tomato plant)	Observation
– Parts of the plant stem immersed into eosin solution and fixed on the slide	– Parts of the sample in the section are red.

Interpretation of results and conclusion

The stem appeared coloured in the activity because the water is rising through the specialized conducting tissues called the xylem. Xylem is involved in uptake of water and mineral elements and phloem is involved in transport of food material from source to the sink.

Xylem and tracheids in the section turn red indicating water moves up in the xylem. It forms a continuous system running from the tips of the roots to the above ground parts (stem) and also to the branches and leaves. It is a complex tissue composed of four types of cells: Tracheids, Vessels, Xylem fibers and Xylem parenchyma.

Guidance on the evaluation

Assess learners on transport in plants by asking some questions such as:

1. Describe how plants get water and minerals from soil and how does food prepared by leaves reach other parts of the plant?
2. What kind of transport system allows the passage of water and food to various parts of plants?

Experiment 8.2: Investigate factors that affect transpiration rates using potometer

This experiment will be done when teaching the concept or topic of transpiration in plants.

Rationale

Most of water absorbed by the root system is not utilized for growth or metabolic processes. It leaves the plant through transpiration. Transpiration is essential to maintain moisture conditions in the environment, where as much as 10% of the moisture in the environment is from transpiration of water by plants. The factors which affect the rate of transpiration in a plant include light, temperature, humidity, wind, and soil water content. It is essential to

investigate experimentally the environmental factors that may affect the rate of transpiration for effective plant conservation which is beneficial to the ecosystem and maintenance of climate.

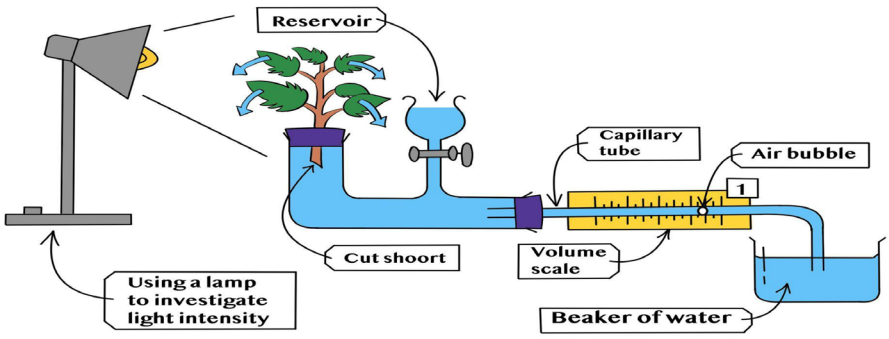
Objective

To investigate the factors that affect the transpiration rate in plants

Materials

1. Potometer
2. Timer
3. Lamp
4. Ruler
5. Plant
6. Rubber stopper
7. Vaseline

Experiment setup



Procedure of the experiment

1. Cut a shoot underwater to prevent air entering the xylem and place it in a tube
2. Set up the apparatus as shown in the diagram and make sure it is airtight, using Vaseline to seal any gaps
3. Dry the leaves of the shoot
4. Remove the capillary tube from the beaker of water to allow a single air bubble to form and place the tube back into the water
5. Set up a lamp 10 cm from the leaf
6. Allow the plant to adapt to the new environment for 5 minutes
7. Record the starting location of the air bubble
8. Leave for 30 minutes
9. Record the end location of the air bubble
10. Change the light intensity
11. Reset the bubble by opening the tap below the reservoir
12. Repeat the experiment by changing the light intensity for example by removing the lamp
13. Calculate the rate of transpiration by dividing the distance the bubble travelled by the time period by using the formula: Rate of transpiration =

Reflection questions

How do light influence plant transpiration?

Data recording

Time (minutes) taken by the bubble to move	Distance (m) moved by air bubble	Rate of transpiration
0	-	0
1	0.75	0.75
2	0.62	0.31

3	0.50	0.17
4	0.46	0.12
5	0.30	0.06
10	0.21	0.02
15	0.12	0.01
20	0.05	0.00

To check

Interpretation of results and conclusion

The rate of transpiration increases with the light intensity. This is shown by the bubble moving a greater distance in the first minute when the lamp was placed closer to the leaf. This is because more stomata tend to be open to maximize photosynthesis. Hence, the more stomata that are open, the more water can be lost by evaporation and diffusion through the stomatal pores. The rate of transpiration may be different from the ones calculated depending on the type of the plant and the light intensity.

The numbers may be different from the ones in the table depending on the type of the plant and the light intensity.

Guidance on the evaluation

Assess learners on the effect of light intensity on rate of transpiration. Ask some questions like:

Experiment 8.3: Investigate mass flow hypothesis in the translocation of sap in phloem

This experiment will be done when teaching the concept or topic of food transportation in plants.

Rationale

The survival of plants depends on both minerals from the soil and synthesized sap during photosynthesis . These substances move using Xylem and Phloem vessels to reach all the parts of the plant. The pressure flow hypothesis also known as mass flow hypothesis is the theory used to explain the movement of sap through the Phloem. It is essential to investigate the mass flow hypothesis in the translocation of phloem sap to better understand plants physiology and safeguard them.

Objective

To investigate the mass flow hypothesis in the translocation of sap in phloem

Materials

1. Concentrated sucrose solutions
2. Diluted sucrose solution
3. Water
4. Two semipermeable membranes
5. Connecting tube (U-tube)
6. Two rubbers
7. Glass tube (cuvette)
8. Retort stand
9. Clamp

Procedure of the experiment

1. Prepare a concentrated sucrose solution;
2. Prepare a diluted sucrose solution;
3. Place the concentrated solution in a semi-permeable membrane A;
4. Place a diluted sucrose solution in a semi-permeable membrane B;
5. Fix each membrane to a rubber;
6. Connect two membranes with a U-tube fixed in rubbers
7. Support the apparatus with a retort stand and clamp
8. Let the two membranes be fully placed in water (as indicated in the experiment set up)
9. Wait for around 30 minutes and note down your observations

Reflection questions

How can we explain the movement of water from roots to leaves?

Data recording

Type of the membrane	Observation
Semi-permeable membrane A with concentrated solution	Water moves-in by osmosis due to the concentration in sucrose solution
Semi-permeable membrane B with diluted solution	Water is being forced out by hydrostatic pressure

Interpretation of results and conclusion

In semi permeable membrane A, concentrated sucrose solution (leaf) has lower water potential. Water flows into it from a high-water potential region (xylem vessel) to a low water potential region (leaf cells) by osmosis.

- This creates high hydrostatic pressure in A and forces sucrose solution to enter into the connecting tube (sieve tube) and pass to B (root cell).
- As the flow of mass from membrane A to membrane B continues, the sucrose solution is pushed along and finally appears in B.
- In B, containing water/dilute sucrose solution, water moves out from a higher water potential region by the hydrostatic pressure gradient produced and redistributed through connecting tubes (xylem vessels) between the two containers.

Guidance on the evaluation

Assess learners on the mass flow hypothesis in the translocation of sap in phloem. Ask questions like:

Discuss the factors responsible for ascent of xylem sap in plants

UNIT: 9 GAS EXCHANGE IN ANIMALS

Experiment 9.1: Dissection of an insect to locate the tracheal system

This experiment will be done when teaching the concept or topic related to gas exchange in insects.

Rationale

The tracheal system of insects is composed of a network of tubes contacting the surface at the spiracles and to the inner region of the body for mediating the exchange of gases between the environment and the respiratory system. The tracheal tubes of insects are positioned longitudinally and transversely. They function on the balancing of the pressure in the body. It is essential to know the structure of the tracheal system to better understand the respiration system in insects.

Objective

To describe the tracheal system of cockroach

Materials

1. Cockroach,
2. Dissecting tray
3. Surgical scissors
4. Chloroform
5. Forceps
6. Scalpels
7. Entomological pins
8. Magnifying lens

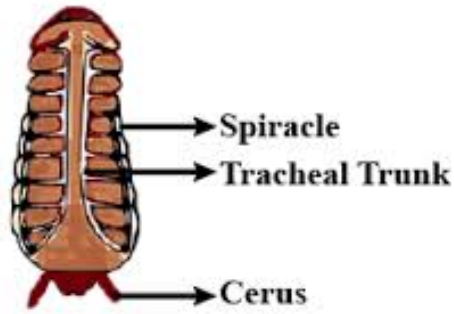
Experiment setup

Procedure of the experiment

1. Obtain a live cockroach
2. Anesthetize the cockroach with chloroform
3. Locate the position of spiracles on thorax and abdomen
4. Fix the insect on a dissecting tray
5. Pin the animal on the dorsal side with the ventral surface facing upwards
6. Carefully remove the abdominal sterna (exoskeleton covering the abdomen) without damaging the internal tissues.
7. Remove the fat bodies and reproductive organs carefully to expose the tracheal system
8. Observe using the magnifying lens or a dissecting microscope

Data recording To check

Draw the tracheal system based on your observation



Interpretation of results and conclusion

In cockroach, the respiratory system is a network of trachea known as the tracheal system. The tracheae connect to external openings spaced along the cockroach's body surface. They respire through small openings called spiracles regulated by muscular sphincters. Cockroaches breathe in oxygen-rich air through the spiracles which open into the tracheal tubes.

Guidance on the evaluation

Assess learners on the respiratory system in insects. Ask questions like:

Describe the tracheal system of insects and relate to its function

Experiment 9.2: Examination of the gills of a fish

This experiment will be done when teaching the concept or topic of gaseous exchange in fish.

Rationale

Gas exchange is crucial for all living things. This allows an organism to get rid of CO_2 and to get oxygen. Fishes use gills for gas exchange in water. Gas exchange through gills is also known as branchial respiration. We need to observe the structure and adaptations of the gills to understand how gas exchange happens in fishes.

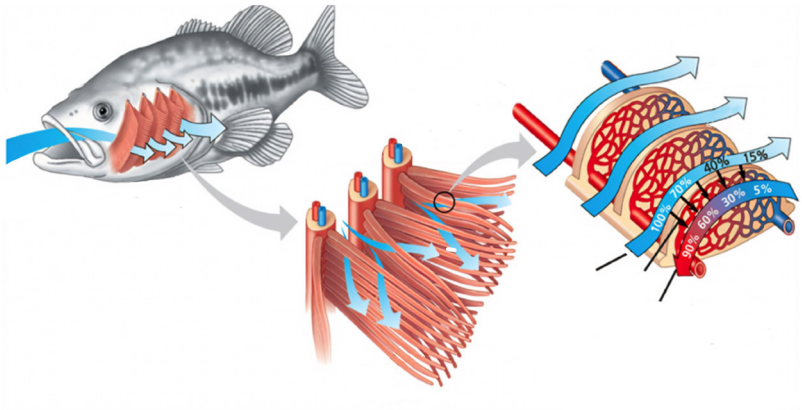
Objective

To examine the gills of a fish

Materials

1. Tilapia or Limnothrissa (isambaza) fish freshly killed
2. Dissection dish,
3. Surgical scissors,
4. Hand lens
5. Prepared slide of fish gill
6. Microscope
7. Dissecting microscope,
8. Glass slide and cover slip
9. forceps

Experiment setup



Obtain heads of freshly killed Tilapia from a local fish market.

Procedure of the experiment

1. Lift the operculum with forceps and locate the organs with red filaments: these are the gills.
2. Using surgical scissors, cut the operculum flush with the eye and up towards the mouth.
3. Count and note the number of gills
4. Cut out a gill with its gill arch and place it in the cup filled with water.
5. Observe the gill with a binocular magnifying glass.
6. Make a captioned observation drawing of this gill
7. Gently remove a single gill filament (cut it out) and place it on the thin section in a drop of water on the slide.
8. Cover with a coverslip.
9. Observe this filament under the microscope.
10. Draw the filament in a 5cm by 3cm rectangle and annotate the drawing using the following captions: gill arch – blood vessels – gill filament

Reflection questions

How does gas exchange happen in a fish?

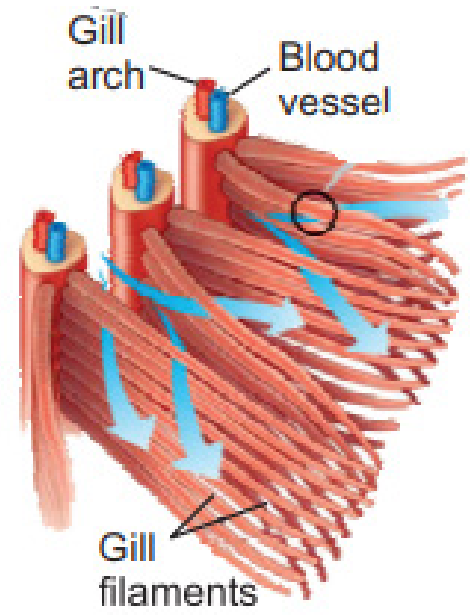
How does the structure of fish's gills help in gas exchange?

Data recording

- Fish gills are red
- Gills are located under operculum
- The gills have differentiated parts

Interpretation of results and conclusion

Gills consist of plate-like structures called filaments or primary lamellae that are covered by an array of lamellae enclosing a capillary blood network which gives them the red color. Fish gills are curved under the operculum and look like lines made of many tiny red filaments. The observed differentiated gill's parts consist of gill arch, blood vessels, gill's filament.



Oxygen-rich water passes through the narrow channels formed by the lamellar layers, where oxygen diffuses into the capillaries.

Source of errors

If the fish died a long time ago, the observation cannot be accurate because the blood in the capillaries would coagulate, and the appearance will tend to be brown. So, better use the freshly killed fish or use living fish that you anesthetize using chloroform.

Guidance on the evaluation

Assess the learners on fish gas exchange system in water. Ask some questions like:

- Describe the structure of the gills in relation to its function.

Experiment 9.3: Observation of ventilation movement of a fish in an aquarium

This activity will be done when teaching the concept or topic related to ventilation mechanism in fish.

Rationale

An aquarium or fish tank is a vivarium of any size having at least one transparent side in which aquatic plants or animals are kept and displayed.

Gas exchange in water is impossible for animals using the lungs yet it is easy for fish. The process can be easily observed through a fish kept in an aquarium. How come that fish does not burst by swallowing water as it breathes? This activity will enable learners to understand this ventilation process.

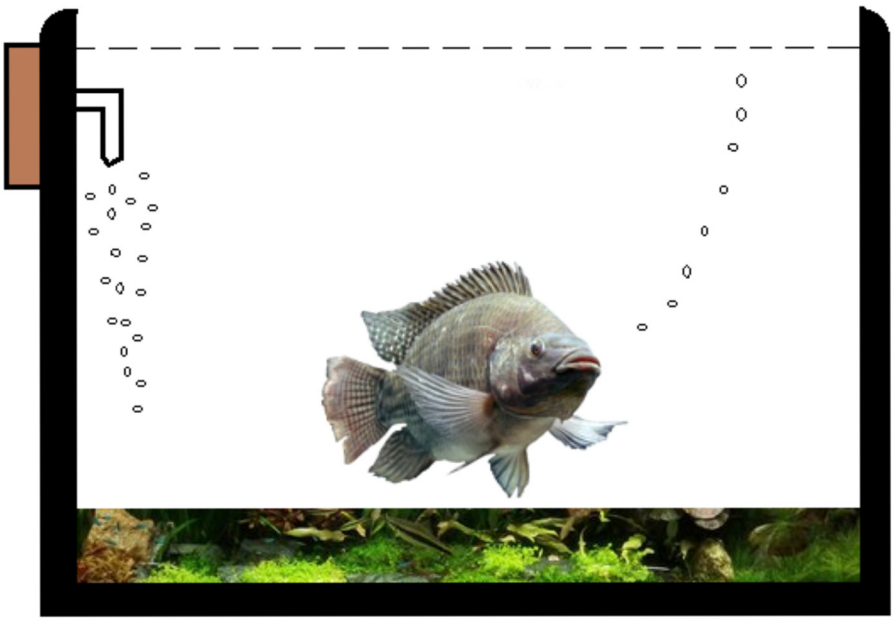
Objective

To observe the ventilation movement of a fish

Materials

1. Living fish
2. Aquarium/Transparent basin of water
3. Notebook
4. Pencil
5. Stop watch

Experiment setup



Procedure of the experiment

1. Observe the movement of the mouth and operculum of a fish in the aquarium/transparent basin.
2. Note your observation focusing on opening and closing of mouth and operculum.
3. Note the number of times the mouth and operculum open per minute.

Reflection question

How come that fish does not burst by swallowing water as it breathes?

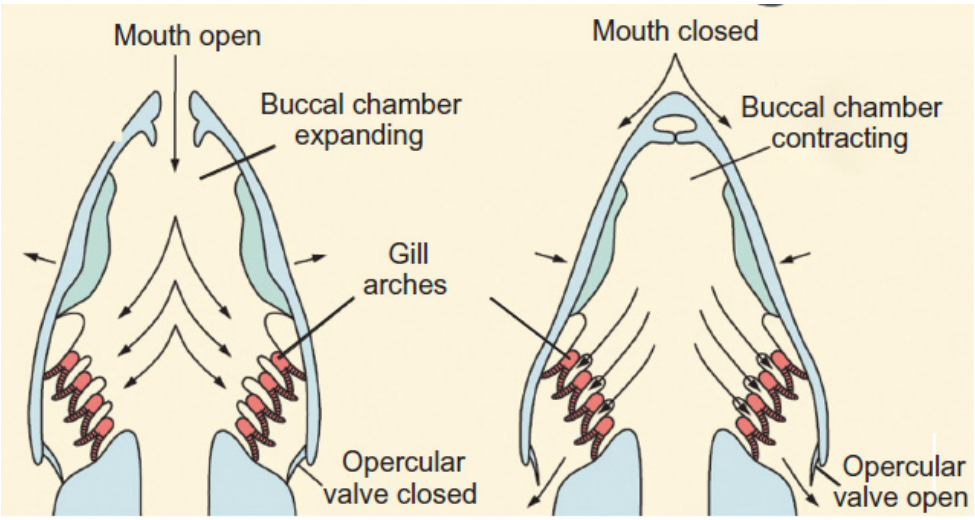
Data recording

- Both mouth and opercula of a fish are repetitively opening and closing.
- As the mouth closes, air bubbles are released on the surface of the aquarium/ transparent basin.
- When the moth closes, the opercula opens widely, and more water is released out.
- There are 18 – 24 breaths per minute.

Interpretation of results and conclusion

During the gas exchange, the fish opens mouth and closes opercula to take in water containing oxygen. Thereafter, it closes the mouth to increase the pressure in the buccal cavity and reduce the volume. Hence, water is pressed over the gill lamellae and runs outside the opercula. As water goes out of the opercula, air bubbles are formed and observed in aquarium.

So, more ventilation is required for oxygen uptake. Ventilation of fish gills is achieved by rhythmic movement of various muscles. This generates a continuous current of water through the gills.



Guidance on the evaluation

Assess learners on ventilation mechanism in fish. Ask some questions like:

Describe the ventilation mechanism in living water fish.

Experiment 9.4: Making a model of human respiratory system

This activity will be done when teaching the concept or content related to the human gas exchange system.

Rationale

Gas exchange is the process by which oxygen and carbon dioxide move between the bloodstream and the lungs. This is the primary function of the respiratory system. It is essential to ensure a constant supply of oxygen to tissues, as well as removing carbon dioxide to prevent its accumulation. The human respiratory system comprises a number of structural parts that complete each other in that gas exchange process. We need to explore these parts and understand the mechanism of gas exchange in humans by using a model made from cheapest raw materials.

Objective

To make a model structure of the human gas exchange system

Materials

1. Plastic air balloons
2. Scissors
3. Plastic straws/Y-shaped tube
4. Liquid glue and scotch tape
5. Big empty plastic bottle/ gas jar
6. Rubber bands
7. Rubber sheet

Experiment setup

Procedure of the experiment

1. Collect required material to make such a model of the human respiratory system.
2. Using strings, tie a balloon to each branched end of the Y-shaped tube
3. Pass the Y- shaped tube through the bottom up to the bottle top
4. Insert the open end of the Y- shaped tube into the bottle top
5. Tie the rubber sheet on the open end of the bottle
6. Use the model to demonstrate the inhalation and exhalation.
7. Study the model and state what each part represents in human respiratory system

Reflective questions

How do different parts of human respiratory system complete each other during respiration?

Data recording

Parts	What it represents in human respiratory system
Big bottle	Thorax
Balloon	Lungs
Y-shape tube	Tracheal canal
Rubber sheet	Diaphragm

Interpretation of results and conclusion

The wall of the plastic bottle represents the thoracic cage.

The rubber sheet at the bottom works like the diaphragm which is a strong muscle that expands and contracts to cause lungs fill with air and then empty out again.

The two small balloons inside the plastic bottle or gas jar mimic the two lungs.

The straws or Y-shaped tube mimic the trachea and bronchi.

The movement of the balloons matches with the breathing. When you breathe in, the lungs fill with air just like the two balloons inside the bottle do. That's because the diaphragm expanded making room for air inside the lung. When you breathe out, your diaphragm contracts (or squeezes in) pushing all the air out of your lungs.

It is also observed that when you pulled down on the rubber sheet, the balloon inflated slightly and when let go, the balloon deflated. Inside your body, you have two lungs that work together, and the diaphragm is below them. Air goes in and out of both of your lungs at the same time.

Precautions

Such a model has limits that you need to consider. Larynx, pharynx, bronchioles and alveoli are not represented in this model. So, never consider this model as 100% that of the human respiratory system.

Guidance on the evaluation

Assess learners on the human gas exchange system structure. Ask some questions like:

Describe the structure of the human gas exchange system.

Experiment 9.5: Observation of a live frog or toad in a glass tank to discuss its gas exchange surfaces

This experiment can be done while teaching the concept or topic related to gaseous exchange in amphibians.

Rationale

Animals have different features that help them to adapt to different environments. Amphibians are the ones having features that allow them to survive in both terrestrial and water. It is important to know how amphibians are differing from other reptiles based on how gases are exchanged in their body.

Objective

Identify gaseous exchange of frog/toad in land and in water.

Materials

1. A live frog/toad,
2. Aquarium/glass tank,

Experiment setup

https://www.bing.com/videos/search?q=how+do+grog+breath&view=detail&mid=3CA276F0258C90026BBA3CA276F0258C90026BBA&FORM=VIRE

Procedure of the experiment

1. Obtain a living frog and put it in an aquarium or glass tank slowly.
2. Observe carefully how it keeps itself ventilated and frequently comes to the surface, etc.

-- While on land observe the video available at: https://www.bing.com/videos/search?q=how+do+grog+breath&view=detail&mid=3CA276F0258C90026BBA3CA276F0258C90026BBA&FORM=VIRE

Reflection question

1. How does the frog respire in the different way in water and on land?

Data recording

Frog respiration	
Location of frog	**Involved Parts**
In water	Moist skin to breath
On land	Lungs and mouth

Interpretation of results and conclusion

A frog uses its moist skin to breathe under water. They don't use lungs to breathe . This kind of respiration is called cutaneous respiration. In land the frog uses lungs for respiration. This respiration is called pulmonary respiration. The frog can also use the buccal respiration, where the month stays permanently closed while the nostrils remain open.

Guidance on the evaluation

Ask learners to make research on the following questions:

1. How do frogs/toads adapt to breathing on land and in water?

UNIT: 10 SMOKING AND RELATED DISEASES

Experiment 10.1: Investigate the harmful effects of tar poison from tobacco

This activity can be done when teaching the concept or topic related to smoking and related diseases

Rationale

Tar is a chemical substance that is produced when tobacco is burned. The tar contains most of the cancer-causing chemicals in tobacco smoke. When inhaled, this tar can have a damaging effect on the lungs and contribute to serious health problems.

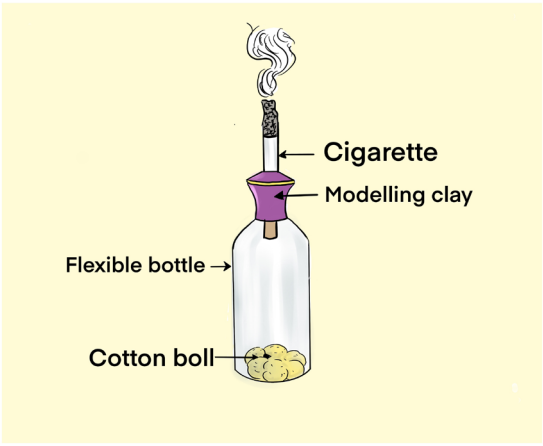
Objective

To identify the harmful effects of smoking

Materials

1. Cigarette
2. Modelling clay
3. Empty bottle
4. Cotton ball

Experiment setup



Procedure of the experiment

1. Put some cotton bolls inside a flexible plastic bottle.
2. Wrap some modeling clay around the cigarette as shown.
3. Fit the cigarette on the mouth of the bottle with the filter end inside.
4. Light the cigarette end outside the bottle.
5. Squeeze and release the bottle to simulate smoking.
6. When the cigarette is almost finished, remove it from the bottle.
7. Take out the cotton bolls on a petri dish.
8. Touch the bolls with your finger.

Reflection question

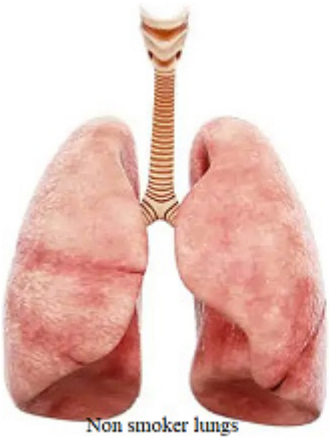
How can we explain the effects of smoking on human lungs?

Data recording

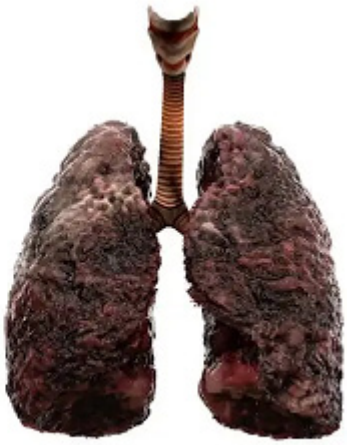
Activity on the bottle	Observation
Push the bottle	The smoke of the cigarette inter inside the bottle
Release the bottle	The smoke of the cigarette get out of the bottle

Interpretation of results and conclusion

As observed in the experiment a flexible bottle represents a person who is smoking the cigarette As the cigarette is almost finished the cotton bowl absorbs chemical substances from the cigarette and becomes black .This also happens to a person who smokes the cigarette. The lungs of the person accumulate the smoke of the cigarette. This smoke contains chemicals that cause lung cancer



Non smoker lungs



Smoker lungs

Guidance on the evaluation

Ask learners the following questions

1. Discuss the effects of smoking on health.
2. What are the measures that can be taken to reduce respiratory diseases caused by smoking?

UNIT: 11

GENERAL PRINCIPLES OF HOMEOSTASIS

Field work 11.1: Making a field study on adaptations of different organisms to different environmental conditions

This activity can be done when teaching the concept or topic related to the adaptation of different organisms to different environmental conditions

Rationale

Every organism has features which enables it to successfully live in a particular habitat. This habitat is controlled by specific environmental conditions such as temperature, humidity, oxygen, and food availability. This field work aims to understand the adaptations of different organisms to different environmental conditions.

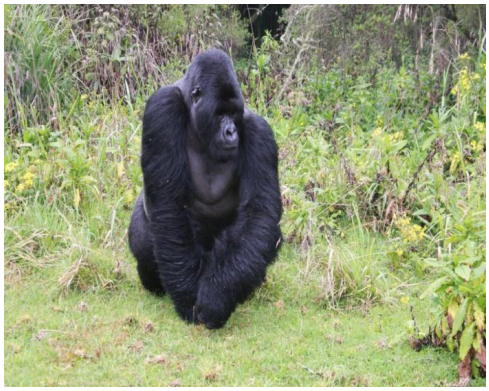
Objective

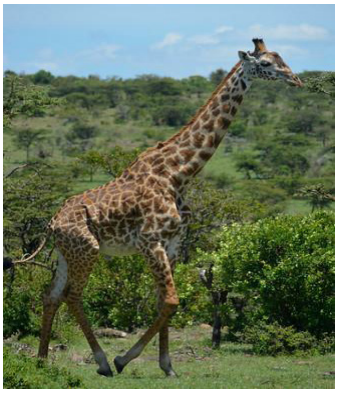
To observe the adaptations of animals to different environmental conditions

Materials

1. Binoculars

Experiment setup





Procedure of the experiment

1. Teacher organizes a field study in Akagera and Volcano National Park to observe different animal behavior.
2. The learners should observe and discuss the environmental conditions in which animals live and survive, focusing on Giraffe, gorilla, and hippopotamus.

Reflection question

Is there any relationship between animal behavior and environmental conditions?

Data recording

Animals	Adaptation	Condition
Giraffe	-Long neck - skin colour	-Feeding in forest canopy, -camouflage
Gorilla	The thick and long fur	Cold environment/ habitat
Hippopotamus	Location eyes, ears and nose on top of the head	Ability to stay in land and in water

Interpretation of results and conclusion

The environment consists of the surroundings in which organisms live and is physical and living. Environments are either terrestrial or aquatic. Aquatic environments are either fresh water or marine. Different places in which organisms live in the major environments are called habitats. Adaptations to

environment are the means used by an organism to obtain food and energy in its particular habitat. Living things adapt themselves not only to their physical environment but also to their living environment, that is, they must adapt themselves to other plants and animals living around them. Although the adaptations are many and varied, they can be categorized into mainly three types: Structural, physiological and behavioral. Examples include the long necks of giraffes for feeding in the tops of trees (Structural), the color of the skin of giraffes helps them to escape from predators (Physiological). The ability of hippopotamus to live both on land and in water, etc..

Note on source of errors

An animal can have more than one adaptation to one or more environmental conditions

Guidance on the evaluation

Assess learners on the adaptations of animals to the environmental conditions. Give them enough time to discuss about animals and their environmental adaptation. You may ask them some questions such as: Write a report on relationship between animal behavior and their environmental conditions

UNIT: 12 REGULATION OF GLUCOSE

Experiment 12.1: Carry out an observation on prepared slides of liver tissue to study its structures and relate to its functions

This experiment can be done when teaching the structure and function of liver tissues.

Rationale

The liver is the second largest internal solid organ in the body after the skin. It performs various functions in the body including synthesis and storage of proteins, fats, carbohydrates, formation and secretion of bile. The liver contributes to the detoxification and excretion of potentially harmful compounds from the body. Knowing the structure and function of the liver is essential to relate the structural parts with their biological functions.

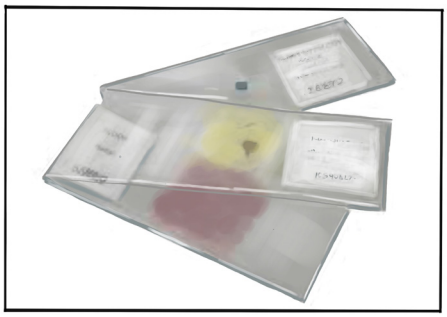
Objective

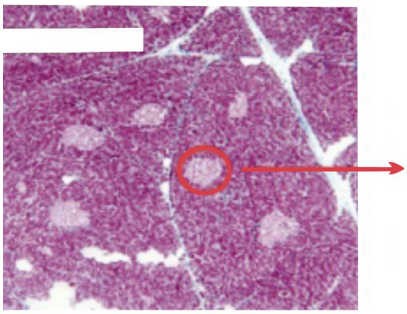
To observe the structure of the liver and relate each structure to its biological function.

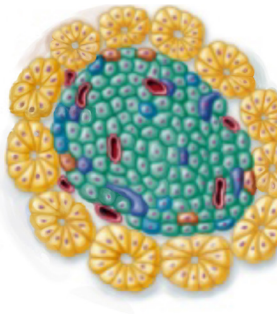
Materials

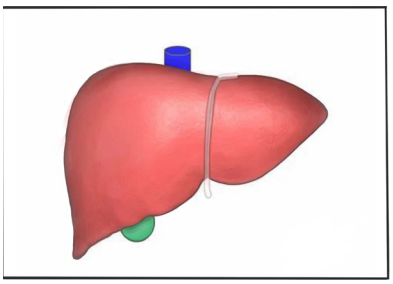
1. Microscope
2. Three permanent slide of liver (Posterior view, anterior view and transversal section of the liver showing liver lobules)
3. Paper
4. Pencil

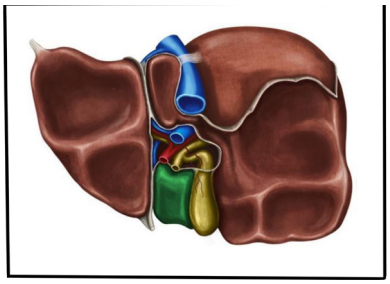
Experiment setup











Procedure of the experiment

1. 1.Set the microscope on the appropriate table in classroom or laboratory
2. 2. Fix the permanent slide of a liver anterior view on the microscope. Observe the mounted slide of the liver posterior view under low and higher magnification,
3. 4. Draw and label the observed image
4. 5. Repeat the steps 1, 2, 3, and 4 on the mounted slide of the posterior and lobules of the liver.

Reflection questions

Is there a relationship between the structures of the liver with their functions?

Data recording

Slide tissue type	Observed structural features	Function
Anterior view of transverse section of the liver	- Two lobes: Right (larger) and left lobes - Round ligament -Coronary ligament -Falciform ligament	The right robe processes blood coming from the head of pancreas pylorus and antrum of the stomach. The left medial segment receives blood from the entire gastro intestinal tract Ligaments keep the lobes of the liver in place
Posterior view of transverse section of the liver	- Caudate lobe - Inferior vena cava - Hepatic artery proper - Common bile duct - Hilus -Left hepatic vein -Hepatic portal vein -Quadrate lobe -Gallbladder	Shows different types of blood vessels and veinules that brings and removes blood in the liver
Liver lobules	- Liver sinusoid - Central vein - Hepatic vein -Hepatocyte - Bile duct - Hepatic artery	Lobules process blood from an incoming from portal venules and send the resulting blood to an outgoing hepatic venules

Interpretation of results and conclusion

The liver consists of 2 main lobes the left and right. The larger right lobe is again sub-divided into three lobes, the right lobe proper, the caudate lobe and the quadrate lobe. Each liver lobe is made up of lobules and different types

of blood vessels each part of the liver plays a specific role such as receiving oxygenated blood and removing wastes when blood is carried out of the liver.

The right robe processes blood coming from the head of pancreas pylorus and antrum of the stomach. The left medial segment receives blood from the entire gastro intestinal tract

Ligaments keep the lobes of the liver in place. Lobules process blood from an incoming from portal venules and send the resulting blood to an outgoing hepatic venules.

Source of errors

- Gallbladder is not among the liver parts

Guidance on the evaluation

Ask learners some questions to check what they captured during the experiment. Questions may focus on the main parts of the liver and their functions. The following are the examples of the questions"

1. What are the main parts of the liver observed in a microscope?
2. Give the biological functions of each part of the liver.

Experiment 12.2: Carry out an observation on prepared slides of pancreas tissue to study its structures and relate to its functions.

This experiment can be done when teaching the concepts or topics related to the structure and function of the pancreas.

Rationale

Pancreas is a glandular organ located in the abdomen. It secretes enzymes that are essential in digestion. Further, it secretes insulin that regulates the energy supply by balancing micronutrient levels during the fed state. The pancreas has two main functions: an exocrine function that helps in digestion and an endocrine function that regulates blood sugar. Knowing the pancreas' functions requires investigating its structural parts through microscopic observation as every feature of the pancreas contributes to a specific biological function.

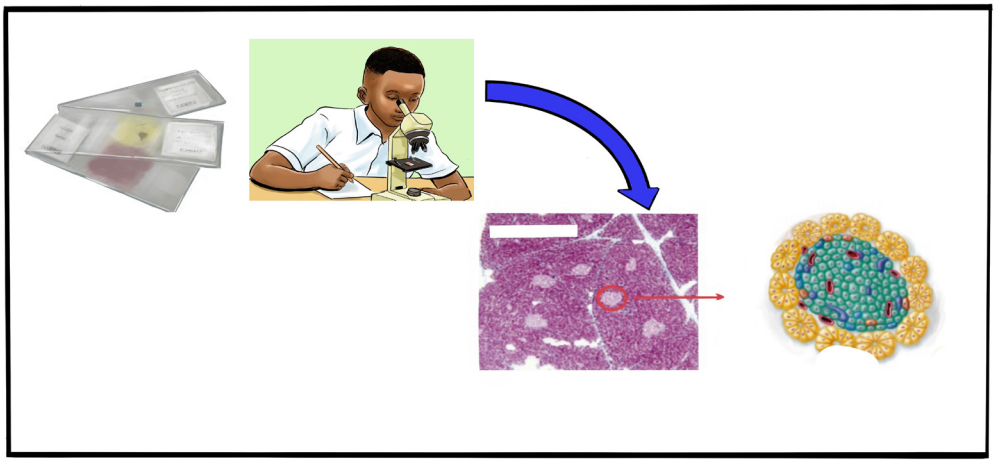
Objective

To observe the structure of pancreas and relate each part with its biological function.

Materials

1. Microscope
2. Permanent slide of pancreas
3. Paper
4. Pencil

Experiment setup



Procedure of the experiment

1. Set the microscope on the appropriate table in classroom or laboratory
2. Fix the permanent slide of a trans-section of pancreas on the microscope
3. Observe the mounted slide of the pancreas transverse section under low and higher magnification,
4. Draw and label the observed image
5. Repeat the steps 1, 2, 3, and 4 on the mounted slide of islet of Langerhans.

Reflection questions

Is there any relationship between the structures of pancreas with their functions?

Data recording

Slide	Observed structural features	Function of the observed parts
Transverse section of pancreas	Two main components : – The Exocrine cells called acini – Islets of Langerhans	– -endocrine system: secretion of hormones namely insulin and glucagon – -Exocrine system: Secretion of enzymes into digestive truct (Lipase, amylase, chymotrypsin).
Islet of Langerhans	– Alpha cells – Beta cells – Delta cells – F cells or Pancreas polypeptide cells	– Beta cells produce insulin – Alpha cells produce glucagon – Delta cells produce somatostatin – F cells or Pancreas polypeptide cells synthesize and regulate the release of pancreatic polypeptide

Interpretation of results and conclusion

Pancreas has two main functional components:

1. The Exocrine cells, the acini: These are cells that release digestive enzymes into the gut via the pancreatic duct. These enzymes include trypsin and chymotrypsin to digest proteins; amylase for the digestion of carbohydrates; and lipase to break down fats.
2. The Endocrine pancreas

contains four different types of cells:

i. Alpha cells: Which secrete glucagon, constitute about 25 percent of all the cells of islet of Langerhans.

ii. Beta cells: The most abundant of the islet cells constitute about 60% of the cells. They release insulin and amylin hormones with unknown function, secreted in parallel to the insulin.

iii. Delta cells: Constitute about 10 percent of total cells and secrete somatostatin which regulates both the alpha and beta cells.

iv. F cells or Pancreatic Polypeptide cells: Are present in small numbers and secrete a polypeptide known as pancreatic polypeptide which inhibits the digestive enzymes produced by the exocrine pancreas.

Source of errors

A poor set up of the microscope may affect the quality of results

Guidance on the evaluation

Assess learners on parts of pancreas and their respective function. Let the learners interpret the images observed by themselves. You may ask them some questions such as:

1. What are the main parts of the pancreas?
2. Give the function of each part mentioned above?

Experiment 12.3: Carry out This experiment can be done when teaching the concept or topic related to the regulation of glucose.

Rationale

Glucose is the main source of energy in living things. Besides being regarded as the universal fuel, glucose also acts as the source of carbon for all the carbon containing compounds of the body. The excess of glucose in urine is called glycosuria. In this case glucose in urine is higher than normal levels of this sugar and may be due to the complication with kidneys or diabetes. It is essential to know the levels of glucose in urine to decide if the individual is normal or suffers from diabetes.

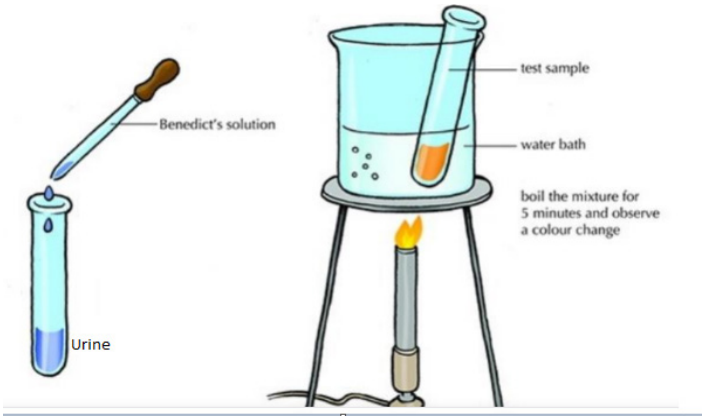
Objective

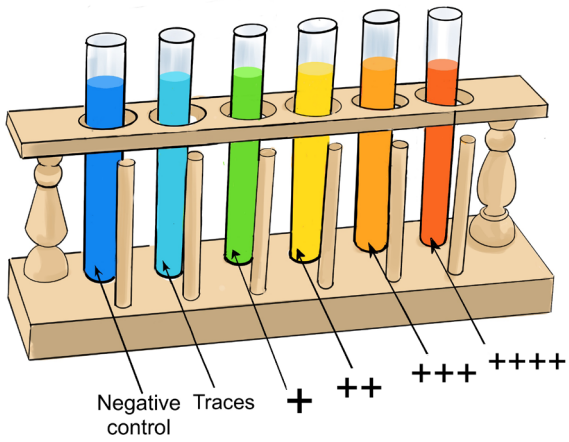
To test the presence of glucose in the urine using Benedict's test.

Materials

1. Benedict's solution
2. Fresh morning urine
3. Dropper
4. Test-tube
5. Test-tube holder
6. Source of heat (Bunsen burner, spirit lamp…)
7. Pipette for measuring the volume of urine
8. Pipette for measuring the volume of Benedict's reagent
9. Water bath
10. Disposable gloves

Experiment setup





Procedure of the experiment

1. Take 1ml of analyte sample (urine) and mix it with 2 millilitres of Benedict's reagent
2. Heat the mixture in a bath of boiling water for 3 to 5 minutes.
3. When there is a development of a brick-red coloured precipitate of cuprous oxide, this confirms the presence of reducing sugars in the analyte (urine).

Reflection question

Is the level of glucose in urine the same for all individuals?

Data recording

Test	Colour of the Precipitate	g% of Reducing Sugar
Urine + Benedict's solution + heat	Green	0.5%
	Yellow	1%
	Orange	1.5%
	Red	2%

Interpretation of results and conclusion

Benedict's test is a chemical test that can be used to check for the presence of reducing sugars in a given analyte. Therefore, simple carbohydrates containing a free ketone or aldehyde functional group can be identified with this test. When benedict' s solution is added to reducing sugars including all monosaccharides (eg glucose, fructose, galactose) and many disaccharides including lactose and maltose, it changes its colour from clear blue to green, yellow, arrange and finally to brick red depending on the amount of glucose in the urine.

Source of errors

Results may be erroneous if the sample of urine is not taken in the morning before taking drinks and food. Do the test no later than two hours after collecting the sample.

Guidance on the evaluation

Assess learners on how to test the glucose contain in urine by using Benedict's solution. Let the learners interpret the results by themselves. You may ask them some questions such as: What can you conclude if the test of glucose in urine shows the following results:

a) Orange

b) Green

c) Yellow

d) Red

UNIT: 13 REGULATION OF TEMPERATURE

Experiment 13.1: Carrying out an experiment to show that enzymes require an optimum temperature

This experiment can be done while teaching the concept or topics related to the regulation of temperature by the body, specifically when teaching the required optimum temperature by enzymes.

Rationale

Enzymes are proteins that act as catalysts for specific biological reactions in living things. These reactions are influenced by body temperature. At low temperatures, reactions slow down because the molecules have less energy. As the temperature increases, the rate of a reaction increases as well. If the temperature is too high, some chemicals in the reaction can be denatured, and the reaction stops. The aim of this experiment is to determine the speed of the reaction of enzymes at different levels of temperature and determine the approximate optimal temperature.

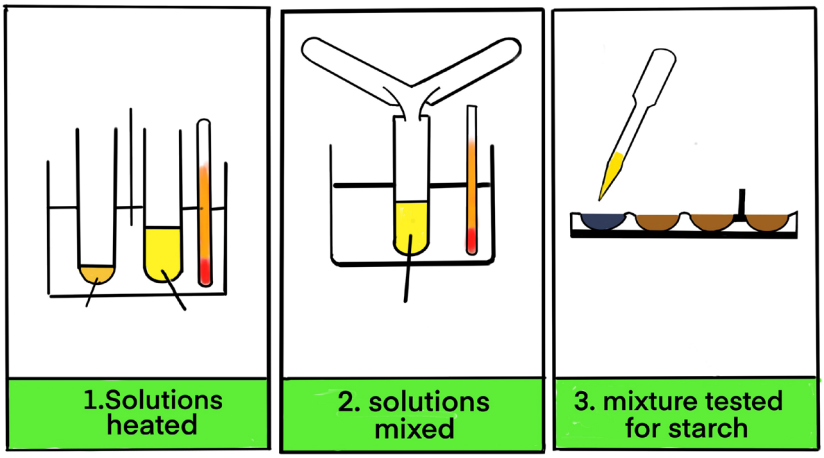
Objective

To determine that enzymes require an optimum df temperature to carry out the biologica function.

Materials

• Water bath • Test tubes • Bunsen burners • Distilled water Iodine solution	• Ice water • Thermometers • Corn starch • Amylase solution

Experiment setup



Procedure of the experiment

1. Pour some water into the water baths and set the temperature at 37°C and 60°C.
2. Make a starch solution by adding 1 g of corn starch to 10 ml of distilled water.
3. Pour the mixture into 50 ml of boiling water and stir until the solution becomes transparent.
4. Prepare amylase solution by adding 2 ml of saliva to 12 ml of water.
5. Take three test tubes and label them as Ice, 37°C and 60°C.
6. Add 4 ml of the starch solution and 4 ml of amylase solution in the three test tubes.
7. Immediately place one test tube in the ice, one in the water bath at 37°C and other at 60°C.
8. Incubate the test tubes for 15 minutes.
9. Take 4 drops of samples from each test tube on a glass plate.
10. Add 1 drop of iodine to each sample.
11. Note the time taken for the iodine to turn yellow from blue.

Reflection question

1. Is there any change observed when a drop of iodine added to the test tube on a glass plate?

Data recording

Temperature	Activity of enzyme
Ice temperature	Iodine takes long time to turn yellow from blue
37°C	Iodine takes less time to turn yellow from blue
60°C	Iodine takes long time to turn yellow from blue

Interpretation of results and conclusion

Enzymes become denatured at high and lower temperatures. However, at the optimum temperature (usually around the body temperature of 37°C), the enzyme catalyzed reactions become high.

Amylase is an enzyme responsible for hydrolyzing starch. During this experiment, the faster the blue color of starch is lost, the faster the enzyme amylase is working. If the amylase is inactivated, it can no longer hydrolyze starch, so the blue color of the starch-iodine complex persists.

In the ice and higher temperature the amylase is denatured. This is the reason why more time was needed for enzymes to digest the starch. At 37° C, the enzyme was active hence takes less time to digest the starch.

Source of errors

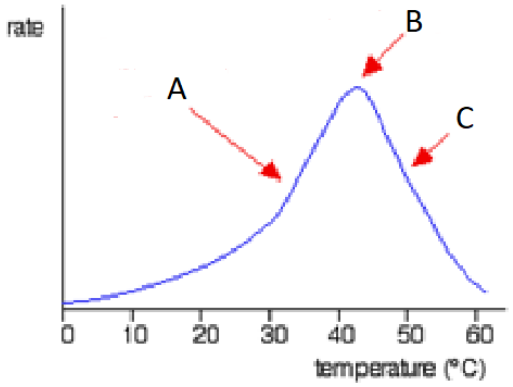
The non-respect of procedures mentioned above may affect the results

Guidance on the evaluation

Assess learners on the effect of temperature on enzyme, showing that enzymes require an optimum temperature to function well. You may ask some questions such as:

1. Why are enzymes not working beyond the optimum temperature?
2. How does the temperature affect the activity of enzymes?

The teacher my also ask learners to interpret the figure below



Experiment 13.2: Investigate the effect of temperature on animal behavior.

This activity can be done while teaching the concept or topics related to the effect of temperature on animal behavior

Rationale

All living organisms have a particular range of temperature within which they can survive and reproduce. When temperature is below or above the animal's body temperature, its biological functions do not take place. The temperature modulates the animal behavior as it affects the required energy outputs to maintain health. It is important to study animal behavior at different temperature ranges.

Objective

To investigate the effects of temperature on animal behavior

Materials

1. Pictures of animals in different environments
2. Video showing animal behavior in different environments
3. Projector
4. Computer
5. Papers
6. Color printer

Activity setup

1. Arctic fox

2. Desert fox

3. Penguins

4.Bats

5. Snails

6. ***Bird***

Procedure of the experiment

1. The teacher may project the pictures above or distribute the colour printed papers to learners (individually or groups), then ask learners to observe them and answer the reflection questions.

Reflection questions

Is there any relationship between animal behavior and environmental temperature?

Data recording

Animals	Environmental factors	Animal behaviors
Arctic fox	Temperature	Reduced size of ears and developed hairs to maintain the body temperature
Desert Fox	Temperature	Developed ears and reduced hairs to reduce the body temperature
Penguins	Temperature	They approach each other to keep their body temperature
Bats	Temperature	They approach each other and sleep for long time to minimize the body activities, and maintain the body temperature

Snail	Temperature	They approach each other, enclose in the shell and sleep for long time to minimize the body activities and maintain the body temperature
Birds	Temperature	They migrate due to changes in environmental temperature

Interpretation of results and conclusion

Animals present different behaviors in accordance with the environmental conditions they live in. Behaviors in this regard can be change in body size, size of body parts (ears, limbs, tails…), and metabolic reactions to maintain the body temperature.

For example, fishes, snakes, lizards, and worms have long and slender body form which ensures rapid heat up and cool down processes.

For instance penguins group together and compact their body shape to maintain their body temperature when it is cold.

Other animals like bats undergo hibernation i.e. finding a warm place to sleep in for a long time.

On the other hand snails undergo aestivation i.e. finding a cold place to sleep in for a long time.

Migratory birds undergo migration when the weather changes. These birds have the ability to detect changes in temperature and migrate to another environment with favorable conditions.

Besides the animals studied in this activity, others such as fishes, snakes, lizards, and worms have long and slender body form which ensures rapid heat up and cool down processes.

Guidance on the evaluation

Assess learners on the effect of temperature on animal behavior by asking them some questions such as:

1. Differentiate hibernation from aestivation
2. Describe different processes in which animals maintain their body temperature

UNIT: 15

IMMUNE SYSTEM, VACCINATION AND ANTIBIOTICS

Experiment 15.1: Describe the blood cell structures using prepared slides of blood smear.

This experiment can be done when teaching the concept or topic related to immune system specifically, the structure of lymphocytes

Rationale

Blood contains many types of cells such as white blood cells (monocytes, lymphocytes, neutrophils, eosinophils, basophils, and macrophages), red blood cells (erythrocytes), and platelets. These cells have different structures according to their specific biological functions. . The experiment aims to describe the structures of blood cells using permanent slides.

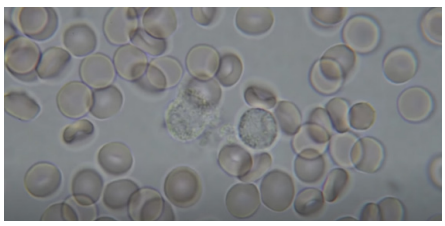
Objective

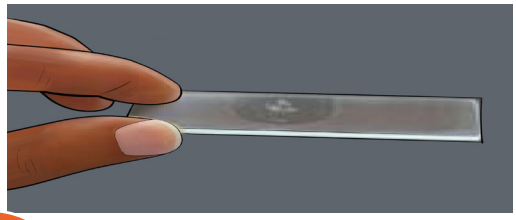
To describe blood cells structures using permanent slides.

Materials

1. Permanent slides of blood smear
2. Light microscope

Experiment setup





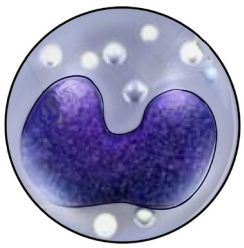
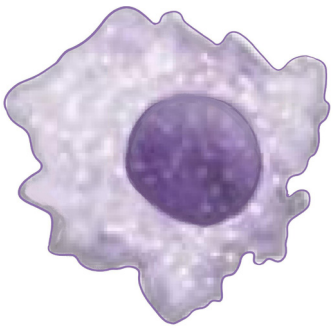
Procedure of the experiment

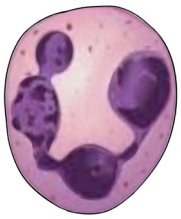
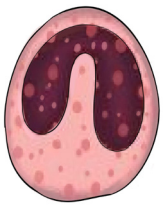
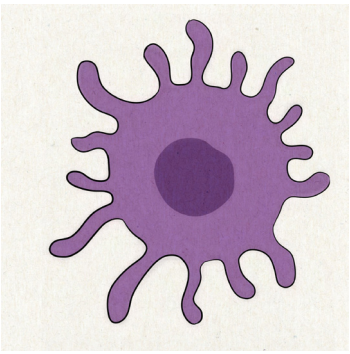
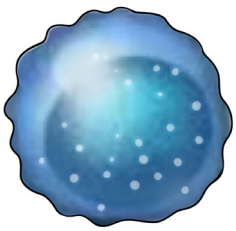
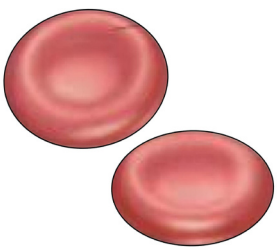
1. Set the microscope on the appropriate table in classroom or laboratory
2. Fix the permanent slide of white blood cells
3. Observe the mounted slide under low and higher magnification,
4. Draw and label the observed cells
5. Repeat the process with the permanent slide of red blood cells
6. Draw and label the observed cells

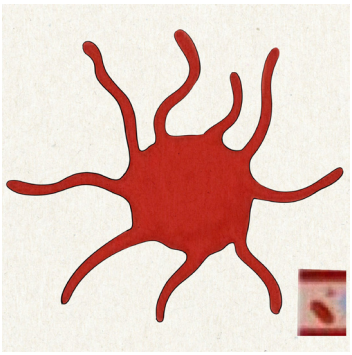
Reflection questions

1. Are there differences between white and red blood cells?

Data recording

	Types of blood cells	Observations	Figure
White blood cell	1. Monocytes	They havekidney-shaped nucleus	
	2. Macrophages	They have a central round nucleus.	 Macrophage

	3. Neutrophils,	They have single and multi-lobed nucleus	 Neutrophil
	4. Eosinophil	They generally have a nucleus with two lobes. (	 Eosinophil
	5. Dendritic cells,	They have round nucleus	
	6. Lymphocytes	They have large anddarkly staining nucleus.	 Lymphocyle
Red blood cell	**1. Red blood cell**	They don't have nucleus	

	2. Platelets	They don't have nucleus	

Interpretation of results and conclusion

There are three types of blood cells including white blood cells (monocytes, lymphocytes, neutrophils, eosinophils, basophils, and macrophages), red blood cells (erythrocytes), and platelets. White blood cells have different types of nuclei while red blood cells and platelets do not have nucleus.

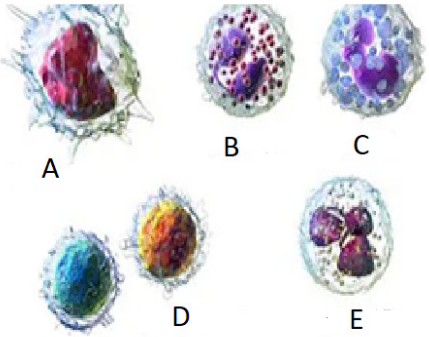
Source of errors

Not well cleaned lenses of microscope may prevent the clear observation of images

Guidance on the evaluation

The teacher can formulate different types of questions such as the following:

1. Eg; Name the cells A, B,C,D



2. Differentiate white and red blood cells

Activity 16.2: Describe the structure of gametes by using prepared slides

This activity can be done when teaching the concept or topic related to structure of gametes

Rationale

The continuity of life for the living things is rooted in reproduction. For the reproduction to take place, there male and female reproductive systems, each producing specific reproductive cells known as gametes. Thus, there male, and female gametes that are also referred to as sex cells. Female gametes are called ovum (plural: ova) or egg cells and male gametes are called spermatozoids. As these two types of reproductive cells are different, there is a need to study the structure of each of them.

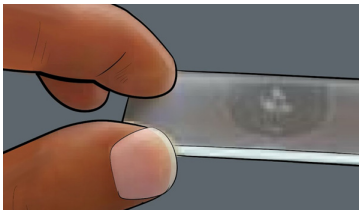
Objective

To describe the structure of gametes using permanent slides

Materials

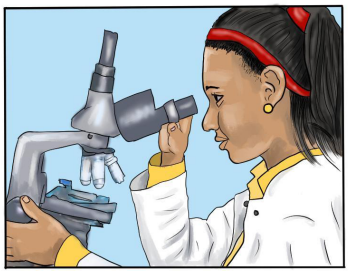
1. Permanent slide of ovum
2. Permanent slide of spermatozoid
3. Light microscope
4. Pencils
5. Rubber

Experiment setup



Permanent slides der a microscope

Light microscope



Observation un-

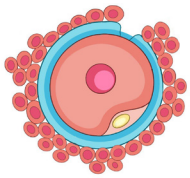
Procedure of the experiment

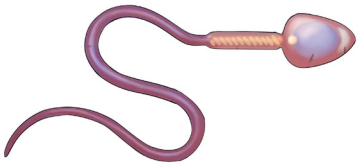
1. Set the microscope on the appropriate table in classroom or laboratory
2. Fix the permanent slide of ovum on the microscope
3. Observe the mounted slide under low and higher magnification,
4. Draw and label the observed cell
5. Repeat the process with the permanent slide of the spermatozoid
6. Draw and label the observed cell
7. Compare the structures of observed cells

Reflection questions

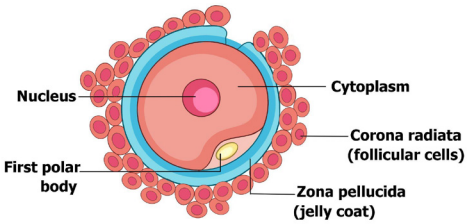
Do the male and female reproductive cells have the same structure?

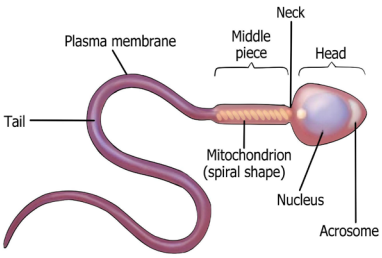
Data recording

Type of the cell	Figure	Characteristics
Ovum		– Round and nearly spherical cell without a tail. – It consists of the central nucleus, cytoplasm, and cell membrane.

Spermatozoid		– Has head containing the nucleus and acrosome, followed by the neck, – Has a middle piece containing mitochondria, plasma membrane and tail

Interpretation of results and conclusion





The female reproductive cell is called ovum (plural: ova). It is a nearly spherical cell without a tail and consisting of a central nucleus, cytoplasm, and cell membrane. On the other hand, the male reproductive cell is called spermatozoid made of head, mitochondrion, plasma membrane and tail. The nucleus is in the head.

We conclude that male and female reproductive cells have different structures, even though some of the parts making these cells might be the same.

Guidance on the evaluation

The teacher may bring annotated figures, where some parts are labeled using letters A, B, C…and ask learners to name the parts. The teacher can also ask questions on the comparison of the structure between male and female human reproductive cells and give the assignment to do research and check if these structures are common to all mammals (rat, rabbit…).

Example of the ques: Compare the structures of human male and female gametes

REFERENCES

1. Rwanda Education Board (2020); Biology Senior Five- Student book, First Edition-Kigali
2. Biological Science by DJ Taylor, G.W. stout, N.P.O Green, R. Soper. • Advanced level
3. Biology (2nd edition) Michael Kent, 2013 Oxford University Press.
4. https://www.youtube.com/watch?v=E5nfVsZcjDc
5. https://www.youtube.com/watch?v=CsfJL-IIVz4
6. https://www.youtube.com/watch?v=RtnLNmB3ZNE
7. https://www.youtube.com/watch?v=36RXIjHMC6g
8. https://www.youtube.com/watch?v=fq2CflK6wCk

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